1968

Appraisal of Water Quality Standards for the Big Sioux River Downstream from Sioux Falls, South Dakota

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APPRAISAL OF WATER QUALITY STANDARDS FOR THE BIG SIOUX RIVER DOWNSTREAM FROM SIOUX FALLS, SOUTH DAKOTA

by

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A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Major in
Civil Engineering, South Dakota
State University

1968

APPRAISAL OF WATER QUALITY STANDARDS

FOR THE BIG SIOUX RIVER DOWNSTREAM

FROM SIOUX FALLS, SOUTH DAKOTA

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Advisor Date

Head, Civil Engineering Department Date

2661-9

ACKNOWLEDGEMENTS

The author wishes to express sincere gratitude to Dr. James N. Dornbush and Dr. John R. Andersen of the Civil Engineering Department for their suggestions, guidance and technical assistance throughout this investigation.

The cooperation of Mr. Roger Weiting and Francis Hauck of the Sioux Falls Wastewater Treatment Plant is gratefully acknowledged for their assistance in providing basic data throughout the investigation.

Funds for this study were provided in part by the United States Department of Interior and the East Dakota Conservancy Sub-District through the South Dakota State University Water Resources Institute as authorized under Public Law 88-379. This study was also supported in part by a Federal Water Pollution Control Administration Training Grant Number 5T1-WP-93-02.

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INTRODUCTION

As a result of the Federal Water Quality Act of 1965 all states of the union were required to develop water quality standards for the interstate waters within their boundaries and after holding public hearings, adopt such standards prior to June 30, 1967 (1-1). The required public hearings for the state of South Dakota have been held, a set of standards has been adopted by the state, and approval by the Federal Water Pollution Control Administration is pending. This study was undertaken in an effort to determine the impact of the surface water quality standards on the Big Sioux River immediately below the city of Sioux Falls, South Dakota. Attempts were made to define existing problems as well as areas which may require further investigation, and to suggest some possible solutions to problems which may arise as action is taken to comply with the standards.

Sioux Falls is the largest center of population and industry in South Dakota. The 1960 census showed the city as having a population of 65,466 (2-5). The estimated 1967 population is approximately 70,000.

Sioux Falls is located on the Big Sioux River near the Iowa - Minnesota border (See Figure 1) and discharges its wastewater into this interstate stream. The flow in this river is highly variable and since the city generates approximately 10-13 million gallons per day (MGD) of wastewater, this flow makes up a significant portion of the total river flow for extended periods of time. However, at times

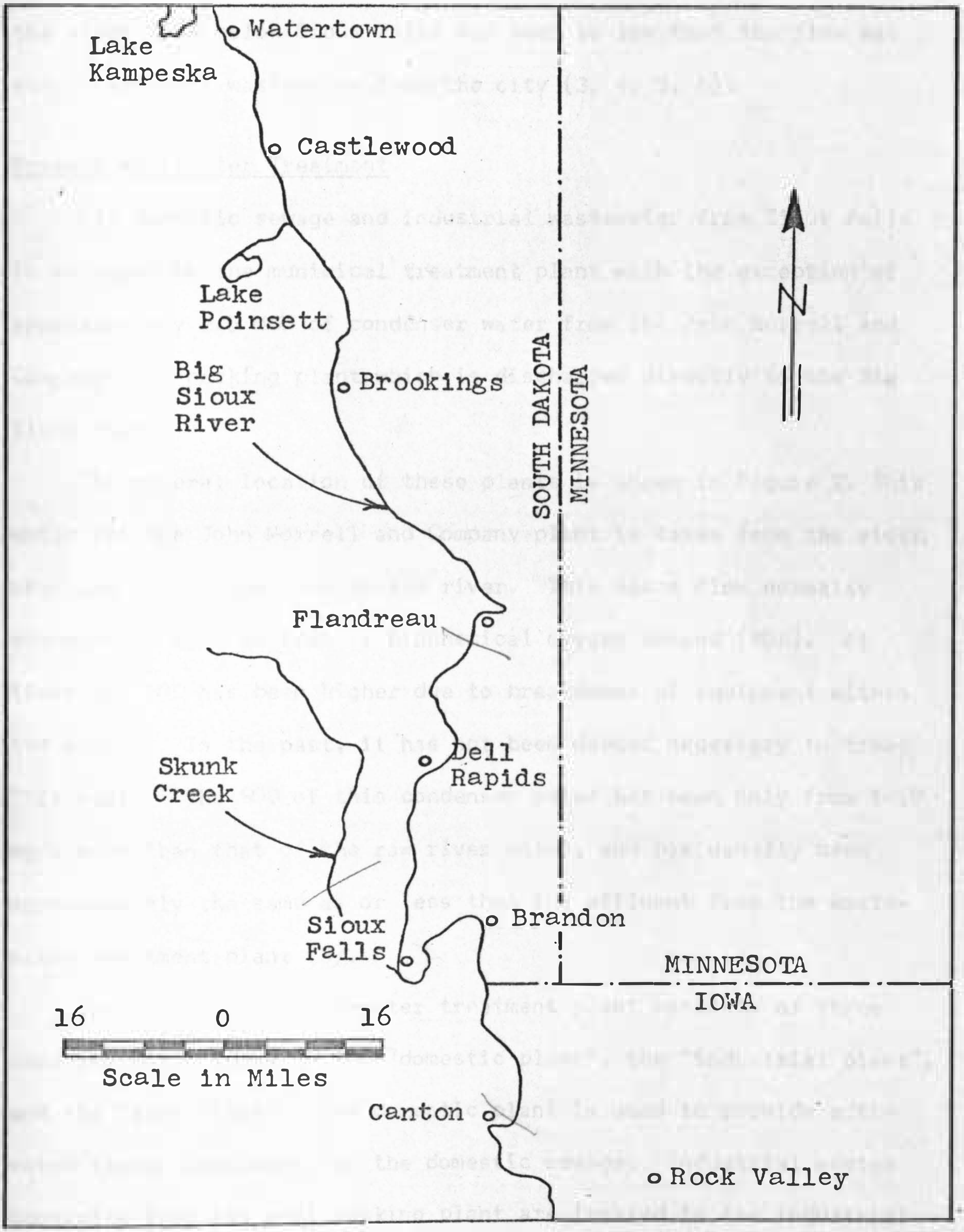

Figure 1. Location Map, Big Sioux River Basin

the river flow below Sioux Falls has been so low that the flow was essentially all wastewater from the city (3, 4, 5, 6).

Present Wastewater Treatment

All domestic sewage and industrial wastewater from Sioux Falls is conveyed to the municipal treatment plant with the exception of approximately 2.5 MGD of condenser water from the John Morrell and Company meat packing plant which is discharged directly to the Big Sioux River.

The general location of these plants is shown in Figure 2. This water for the John Morrell and Company plant is taken from the river, used and discharged back to the river. This waste flow normally averages 20 mg/l or less of biochemical oxygen demand (BOD). At times the BOD has been higher due to breakdowns of equipment within the plant[1]. In the past, it has not been deemed necessary to treat this waste. The BOD of this condenser water has been only from 1-10 mg/l more than that of the raw river water, and has usually been approximately the same as or less than the effluent from the wastewater treatment plant (3).

The Sioux Falls wastewater treatment plant consists of three separate parts known as the "domestic plant", the "industrial plant", and the "army plant". The domestic plant is used to provide activated sludge treatment for the domestic sewage. Industrial wastes generated from the meat packing plant are treated in the industrial

[1]Personal correspondence with personnel of John Morrell and Company, Sioux Falls, South Dakota.

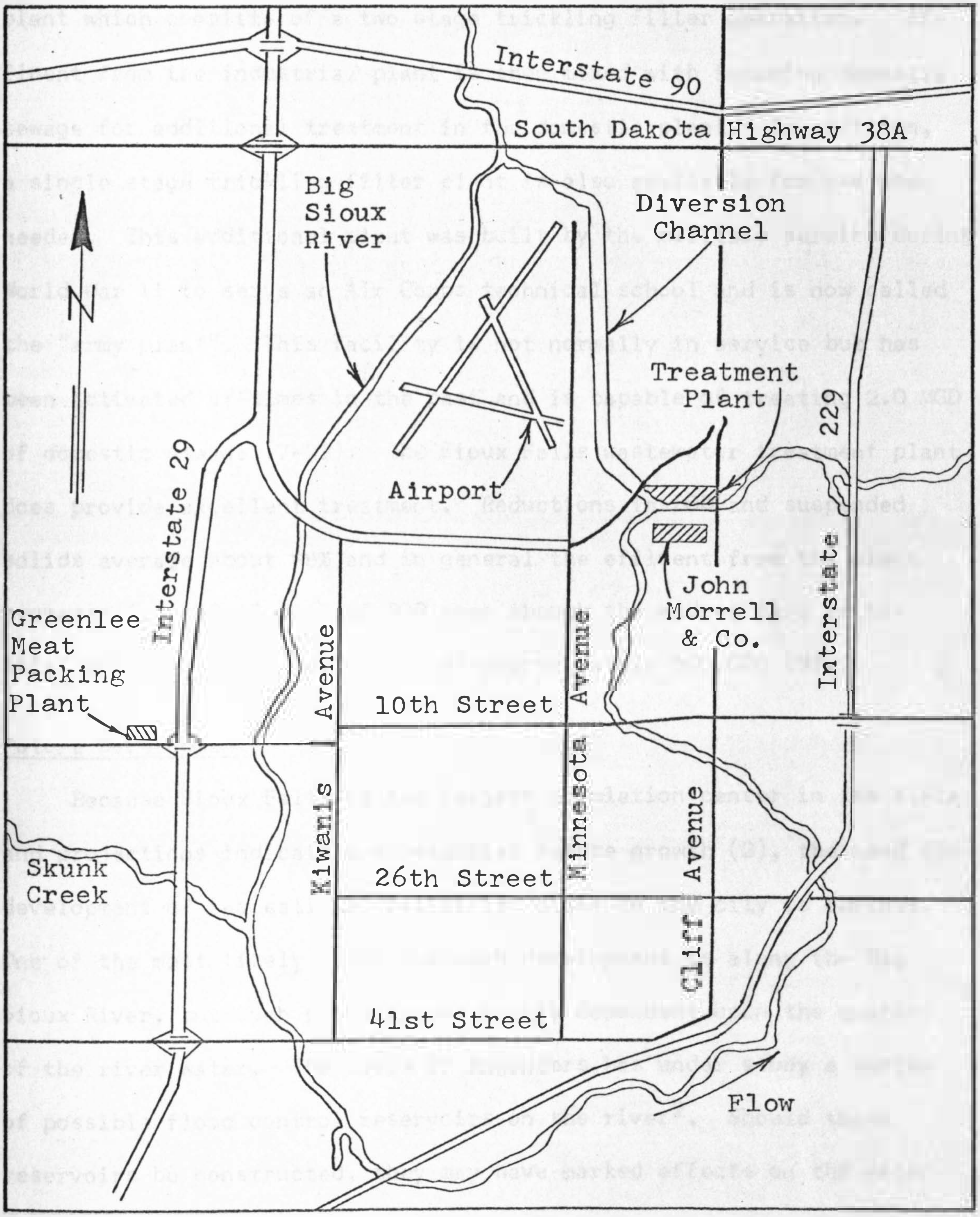

Figure 2. Map of City of Sioux Falls

plant which consists of a two stage trickling filter operation. Effluent from the industrial plant is then mixed with incoming domestic sewage for additional treatment in the domestic plant. In addition, a single stage trickling filter plant is also available for use when needed. This additional plant was built by the military service during World War II to serve an Air Corps technical school and is now called the "army plant". This facility is not normally in service but has been activated at times in the past and is capable of treating 2.0 MGD of domestic sewage (7-23). The Sioux Falls wastewater treatment plant does provide excellent treatment. Reductions in BOD and suspended solids average about 98% and in general the effluent from the plant averages from 20-30 mg/l of BOD even though the wastes have an initial BOD population equivalent of approximately 500,000 (3).

Future Development

Because Sioux Falls is the largest population center in the state and projections indicate a substantial future growth (2), the need for development of recreational facilities close to the city is obvious. One of the most likely areas for such development is along the Big Sioux River, but such projects are highly dependent upon the quality of the river water. The Corps of Engineers has under study a series of possible flood control reservoirs on the river[2]. Should these reservoirs be constructed, they may have marked effects on the water

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[2]Personal Correspondence with personnel of the Omaha District Corps of Engineers, Omaha, Nebraska.

quality in the river and exert considerable influence on the feasibility of future recreational developments. All of these factors plus others require careful evaluation in order to determine and to control the water quality in the Big Sioux River. It was also the purpose of this study to investigate the possible influence of reservoirs upon the river water quality and to offer suggestions in this regard as to what future action might be advisable in order to obtain the maximum benefits from the river.

LITERATURE REVIEW

South Dakota Surface Water Quality Standards

In order to fully comprehend the following discussion, some background factors should be provided so that the framework within which the surface water quality standards were written can be fully appreciated. The primary factors considered were natural water quality, important pollutants, existing and potential beneficial uses, enforcement problems, and federal requirements (1-1). Of these, the first three were the most important for this study and are the only ones which will be discussed in detail.

The natural water quality of most South Dakota rivers and streams is quite erratic due primarily to extreme seasonal variations in flow and the geology of the area. Cations such as calcium, magnesium, sodium, and potassium as well as the anions of bicarbonate, chloride, and sulfate are present to some degree in all waters. Total hardness of 500 mg/l or more in the river waters of the state is not uncommon and suspended solids concentrations in excess of 20,000 mg/l often occur during periods of high flow. Most surface waters in the state contain concentrations of the above pollutants in amounts greater than those deemed desirable for irrigation and domestic or industrial water supplies. When criteria for the various beneficial uses were set, consideration was given to the existing low quality.

Relatively speaking, however, the water of the Big Sioux River is of somewhat better natural quality than most other rivers in the state. While several factors probably contribute to this better quality, two are readily identifiable. First of all, the Big Sioux River drainage basin is located in the highest rainfall area of the state; secondly, a significant portion of the water during low flow periods is probably from the alluvial sands and gravels which underlay the basin and contain waters of good quality (8-210).

Pollutants which enter the streams of South Dakota are primarily from municipal or industrial wastes and agricultural runoff from cultivated land and feed lots or barnyards (1-2). All of the above potential sources do exist either in the city of Sioux Falls or along the Big Sioux River downstream from the city. While the industrial and municipal wastes can be largely controlled and treated, it is extremely difficult to control agricultural runoff from all farming operations in the area. These sources are probably the origin of an undetermined amount of pollutant matter which eventually does find its way into the river.

Beneficial use categories for the waters of South Dakota were prescribed for the various lakes and watercourses while keeping in mind the naturally poor water quality encountered in many areas. These different categories are as follows: Domestic Water Supply, Fish Life Propagation, Recreation, Wildlife Propagation and Stock Watering, Irrigation, Commerce and Industry, and Intermittent Stream. Because poor natural water quality limits the use of many streams for irrigation purposes, this use was assigned only to streams along which irrigation is now practiced or studies have shown that irrigation is feasible. Since it is expected that surface waters in

South Dakota will not be further developed to any great extent for domestic water supplies due to cost of treatment, poor natural quality, unreliable flows, etc., this use was not assigned except in isolated cases. Wildlife Propagation and Stock Watering was assigned to all waters in the state because they are used for this purpose to at least a limited extent (1-6).

The beneficial uses assigned to the Big Sioux River downstream from Sioux Falls were Fish Life Propagation, Limited Contact Recreation, Wildlife Propagation and Stock Watering, Irrigation, and Intermittent Stream (1-36). The exact criteria for and descriptions of these different categories are discussed in subsequent sections.

In all cases the limiting values specified in the standards for the different pollution parameters are limits for the river water and not an effluent standard. A stream standard limits the total amount of polluting matter present in the water by placing specific limits on the concentrations of BOD, suspended solids, etc. Had the effluent standard approach been adopted, limits would have been placed upon the pollutant characteristics of each waste stream entering the river or lake rather than the surface waters, per se. While stream standards are probably more difficult to enforce intelligently, this concept as embodied in the South Dakota Water Quality Standards is generally thought to be more effective as a tool for maintaining stream quality than the effluent standard approach (9-54).

In addition to specified limits or ranges for the values of the different parameters, a system to allow deviations from these limits based on sample frequency was incorporated into the standards. This system is indicated in the standards and throughout this report by a frequency code identified as a, b, c, or d (1-15). A detailed explanation of these frequency codes is contained in Appendix A.

Sources of Data and Related Studies

During past years, data as to flow rates, water quality and amounts of polluting matter introduced into the Big Sioux River at and downstream from Sioux Falls has been gathered by various agencies. Evaluation of this existing data provided the framework within which this investigation was conducted and only an extremely limited number of additional measurements were performed to gather additional information.

From August, 1943 through September, 1960 a flow gaging station was maintained on the Big Sioux River at Sioux Falls by the United States Geological Survey (U.S.G.S.). Because a channel was constructed to divert water around the above station, the U.S.G.S. began operation of another gaging station near Brandon, South Dakota approximately nine miles downstream from Sioux Falls in July, 1959. This station is still operational (4, 5). All river flow data used throughout this study was for these two stations.

A review of the flow data confirmed that the Big Sioux River does exhibit large variations in flow rate during different times of the year. Normally, during the latter part of March the flows from spring runoff have been experienced. At these times flow rates in excess of 1,000 cfs have been common for several days. During the months of January and February the lowest flows of the year have usually taken place and during these times river flows of 20 cfs or less have been recorded for extended periods of time (4, 5, 6).

Since May, 1961 a water quality analysis program has included a Big Sioux River sampling point near Brandon, South Dakota. This program was initially begun by the United States Public Health Service and weekly tests were made for radioactivity levels, plankton populations, and chemical, physical, and bacteriological characteristics of the water. Responsibility for operation of the program was later shifted to the Federal Water Pollution Control Administration (10). Quality data actually used for this investigation covered the period from June, 1961 through June, 1966 (11, 12). Data for periods after June, 1966 was not available. Other sources of water quality information which were utilized included various unpublished records of the United States Geological Survey and the FWPCA. In addition some tests were performed expressly for this investigation by personnel of the Sioux Falls wastewater treatment plant (13).

Operational records for the Sioux Falls wastewater treatment plant provided the bulk of the data as to the amount of polluting matter actually entering the river. These reports gave information as to the volumes discharged to the stream and the polluting capability (BOD, suspended solids, etc.) of the plant effluent (3). In addition to these reports, data on the BOD and estimated daily flow of condenser water from the meat packing plant was obtained from John Morrell and Company. These two sources were considered to be the primary contributors of controllable pollutant flow.

One other source of Big Sioux River pollution is from the system of waste lagoons operated by Greenlees Meat Packing Company. These lagoons are presently overloaded and contribute about 0.5 MGD of partially treated meat packing waste to the river west of Sioux Falls (See Figure 2). It has been estimated that the population equivalent of this waste is approximately 2,125 or 380 pounds of BOD per day (1-61). However, this amount is rather inconsequential when compared to that emanating from the two major sources. Also, since the point at which this load is introduced into the river is some five miles upstream from the wastewater treatment plant the waste is probably fairly well stabilized by the time it reaches the plant outfall and may exert only a minimal effect upon water quality further downstream. Accordingly, this wasteflow was not considered to be a significant factor to the study of water quality downstream from Sioux Falls.

Another source of data includes a study (7) of present and future wastewater treatment requirements for Sioux Falls. This study (7) has been completed and it is thought that with minor additions and modifications, the facilities that presently exist will be adequate until the year 1985. The recommended changes consist of the addition of one final clarifier in the near future, one additional aeration tank in 1977, and certain modifications of the flow pattern of wastewater within the plant. In 1985 it is reported that additional treatment facilities will be required and these should be adequate to treat the expected waste flows until the year 2010 (7-43). It is now planned that the additional final clarifier will be in operation by late Summer or early Autumn of 1968. The other recommendations for future expansion will probably be implemented when the actual need arises.

Correspondence has indicated that the Corps of Engineers has under study a possible system of five flood control reservoirs on the main stem and tributaries of the Big Sioux River. Two of these sites are upstream from Sioux Falls and three are downstream. One of the up-stream sites is on the main stem near Flandreau; and the other is on Skunk Creek, a tributary of the Big Sioux River which enters the river at Sioux Falls. The downstream sites being considered are one near Canton and two other sites located on tributaries farther downstream. Of the five sites, only the first three mentioned were of concern to this study.

Although the primary purpose of these reservoirs would be flood control, other benefits could also be derived. For instance, if sufficient storage were available in the reservoirs upstream from Sioux Falls, it would be possible to make controlled discharges from these reservoirs at times of normal low flow in the river. This in turn would provide additional dilution for the wastewater flows from Sioux Falls thus improving the downstream water quality. The Corps of Engineers has given some consideration to this aspect (14-3).

In addition to low flow augmentation, the possible recreational benefits to be derived from the reservoirs could be substantial as fishing, swimming, and picnicking areas would be provided; whereas, at present such facilities are quite limited. For all these possible uses however, the water quality in the reservoirs is a critical consideration. If nuisance conditions were to develop or if good quality dilution water could not be provided the additional benefits would not be possible.

Water Quality in Reservoirs

Public Law 660 as amended by Public Law 87-88 requires that in the overall planning of any reservoir by any federal agency, consideration must be given to water storage for regulation of stream flow for the purposes of water quality control (15-1). If such systems are to be widely utilized however, it is required that changes in water quality which result from reservoir storage be well understood. This is necessary so that water releases from reservoirs are of good quality and will be beneficial rather than detrimental to water uses downstream. At present there is insufficient knowledge upon which to base these judgments with any degree of certainty. As a result, streamflow regulation for water quality control has been practiced with varying degrees of success (16-4).

The basic premise of reservoir utilization for water quality control is that at times of high flow, water could be stored while at times of low flow, water could be released to maintain downstream flow rates at certain required levels (16-4). In the case of the

Big Sioux River downstream from Sioux Falls, such additional dilution could possibly maintain a more favorable environment for fish life thus avoiding the possibility of fish kills which could take place at times of very low flow. In addition these releases could improve the overall water quality of the river.

In general, the most important single characteristic of a water which is to support fish life appears to be the dissolved oxygen content. As a result of thermal stratification and other factors which exert influences in reservoirs, the bottom layers of water often become stagnant and are either devoid of or contain very little dissolved oxygen (16-18). Release of such a water would obviously not be of assistance in maintaining fish life at downstream locations, but would impose a hardship. However, dissolved oxygen levels of reservoir waters are not the only problem which is likely to be encountered. In some cases an absence of fish life below dams which discharged bottom water has been noted even though the water was reaerated. This has led to the supposition that in some reservoirs, other substances toxic to fish life have been formed (15-51).

Another condition which is more commonly encountered when stream waters are impounded is that extensive nuisance algal growths are developed (15-4). When the flowing water of a river is placed in an impoundment, sedimentation occurs which allows sunlight to penetrate to greater depths. If the nutrients required by algae are also present, extensive algal growths are apt to develop. These growths result in a very unsightly appearance and produce other unaesthetic conditions which severely restrict any recreational uses of the water.

Of the nutrients required for algal growths, nitrogen and phosphorous are among the most important. From research conducted on lakes near Madison, Wisconsin, Sawyer (15-9) has shown that most of the lakes which produced nuisance algal blooms had organic phosphorous concentrations in excess of 0.10 mg/l. His data concerning critical levels of inorganic phosphorous indicated that nuisance conditions could be expected when the concentrations of inorganic phosphorous were equal to or greater than only 0.01 mg/l. This same study indicated that the critical level for nitrogen was 0.30 mg/l of inorganic forms. However, it was also shown that extensive algal growths could be produced under laboratory conditions with a plentiful supply of phosphorous but less than critical levels of nitrogen. Sawyer felt that in this situation, some sort of nitrogen fixation took place, either bacterial or algal, which bridged the deficiency and produced sufficient nitrogen. In the absence of sufficient phosphorous however, nitrogen fixation was found to be of no consequence (15-9).

While nitrogen and phosphorous appear to be the most important of the algal nutrients, it appears that others in more or less trace amounts are also required. Maloney (15-11) has reported that precipitation of iron as iron sulfide because of the formation of hydrogen sulfide has prevented algae growths in lake waters. This would seem to indicate that iron is another required nutrient. Other investigators have found that magnesium, potassium, molybdenum, plus other trace elements and certain vitamins are required for growths of certain species of algae though in much smaller amounts than are nitrogen and phosphorous. Thus while nitrogen and phosphorous appear to be the most critical nutrients, other requirements must also be satisfied in order for growths to take place (15-10). In general however, the critical nitrogen and phosphorous concentrations as found by Sawyer are widely quoted, and nuisance algae growths can probably be expected to result if these concentrations are exceeded providing other environmental conditions are favorable.

INTERMITTENT STREAM USE CATEGORY

General

The Big Sioux River downstream from Sioux Falls exhibits wide seasonal variations in flow rate and in past years flows of 20 cfs and less have been recorded at Brandon for extended periods of time (4). At present, the daily average flow to the municipal wastewater treatment plant is about 10 MGD (3) and approximately 2.5 MGD of condenser water from John Morrell and Company is also discharged directly to the river. It is apparent then, that at certain times of the year, well over 50% of the total flow in the Big Sioux River below Sioux Falls could be wastewater from the city.

In recognition of this situation wherein 50% or more of the total flow in a watercourse is wastewater, the South Dakota Committee on Water Pollution has adopted the intermittent stream use category as one of the legitimate beneficial uses for watercourses in the state. The provisions governing this use, state that most watercourses in which the natural stream flow is less than the daily average waste flow or the daily average irrigation return flow are to be placed in this category and so remain until the natural stream flow has exceeded the daily average waste flow for seven consecutive days. (The only watercourses exempted from this provision are those which have been designated as permanent fishing waters). Whenever the intermittent stream use is in effect, the quality criteria for this category are to apply. When natural stream flow has exceeded the daily average pollutant or irrigation return flow for seven consecutive days, the river is to revert to its other assigned beneficial use(s) and the criteria for these use(s) will once again apply (1-15).

The intermittent stream use category is not permissive nor does it allow that any but well treated wastes can be discharged. The quality standards specify that, "All wastes discharged to streams, lakes, or reservoirs in this category shall have been subjected to at least secondary treatment or its equivalent and, if prescribed by the committee, approved tertiary treatment shall be provided." (1-25). Thus, this category is quite restrictive as to what wastes may be discharged to watercourses in which little or no dilution water is available. A summary of the quality criteria for this category is presented in Table 1.

It is obvious then that Sioux Falls is not advantageously situated for wastewater disposal. The daily volume of wastewater is considerable at present and is certain to increase in future years while the amount of dilution water will continue to be limited unless some supplementary source can be made available. Also, since Sioux Falls is the largest center of population in the state, the need for recreational facilities in the close proximity of the city is apparent. One of the most logical areas for such development is along the Big Sioux River and if this could be accomplished, the intrinsic value to the people of the city would be very substantial.

Table 1. Quality Criteria for Intermittent Stream Use Category

Parameter	Limit	Frequency Code	Data Available
Coliform Organisms	Not to exceed a MPN or MF of 20,000 per 100 ml as a monthly average; nor to exceed this value in more than 20% of the samples tested in any one month; nor to exceed 50,000 per 100 ml in any of the samples tested.		Yes
Biochemical Oxygen Demand (5 day @ 20° C)	30 mg/l	b	Yes
pH	Greater than 6.0 and less than 9.5	a	Yes
Suspended Solids	30 mg/l	b	No

The amount of time during which the Big Sioux River would be in the intermittent stream category is a vital consideration in the planning for recreational and other uses of the river because water quality at this time may be substantially degraded. All other beneficial uses would be adversely affected because when the intermittent stream use is applicable these other categories are not considered in the maintenance of water quality. It is possible that the quality of the river water would be suitable for some uses even though the intermittent stream use did apply, but if so this would be only incidental and not a requirement of the quality standards.

For this portion of the evaluation, it was decided to focus primarily upon two separate three-month periods of the year. The months of December, January, and February were selected as being most representative of the winter conditions apt to produce the most severe problems with water quality during the colder time of the year. This should be the case as the lowest flows of the year have generally occurred during the months of January and February (4, 5, 6) while at the same time an ice cover may be present which would limit reaeration of the river.

The months of July, August, and September were selected to represent the warmer time of the year. Again, these months were chosen on a basis of when the most severe warm weather conditions could be expected. During these months the lowest warm weather flows have normally been recorded (4, 5, 6). The sewage flow is apt to be somewhat greater due to increased water usage during the summer, and the warm temperatures are most conducive to increased biological activity which results in a more rapid degradation of polluting matter introduced into the river.

Deficiency curves were prepared from the flow data which had been gathered for stations along the Big Sioux River in order to evaluate the frequency in which the river would revert to the intermittent stream use (4, 5, 6). These curves depict graphically the per cent of time during which river flow was less than certain values and were prepared from data for the years 1944 through 1966. The gaging station from which the flow data for one set of curves was gathered was located at Sioux Falls from 1944 through 1960. In June, 1959, another gaging station began operation near Brandon, South Dakota; from data gathered at this station another set of curves was prepared. The Sioux Falls gaging station was abandoned after September, 1960 (5, 6). Two sets of curves were required in that the waste water flow from Sioux Falls was not included in the flows measured at the first station whereas this flow is included in the measurements which are made at Brandon.

Frequency of Occurrence at Present Wastewater Flows

In order to ascertain how often the Big Sioux River would revert to the intermittent stream use at present wastewater flows during a year of average stream flow, data as to the average daily wastewater flows from Sioux Falls was obtained and compared with past flow rates in the river. The wastewater flows considered were those from the municipal treatment plant (3) plus the 2.5 MGD of condenser water from John Morrell and Company. For the years of 1962 through 1966 this total daily average wastewater flow was 12.2 MGD or 18.9 cfs.

To estimate the per cent of time during which the intermittent stream use would apply using data from the Sioux Falls station (Figure 3) the pollutant flow cited above was plotted on the deficiency curve. The per cent of time that the river flow would

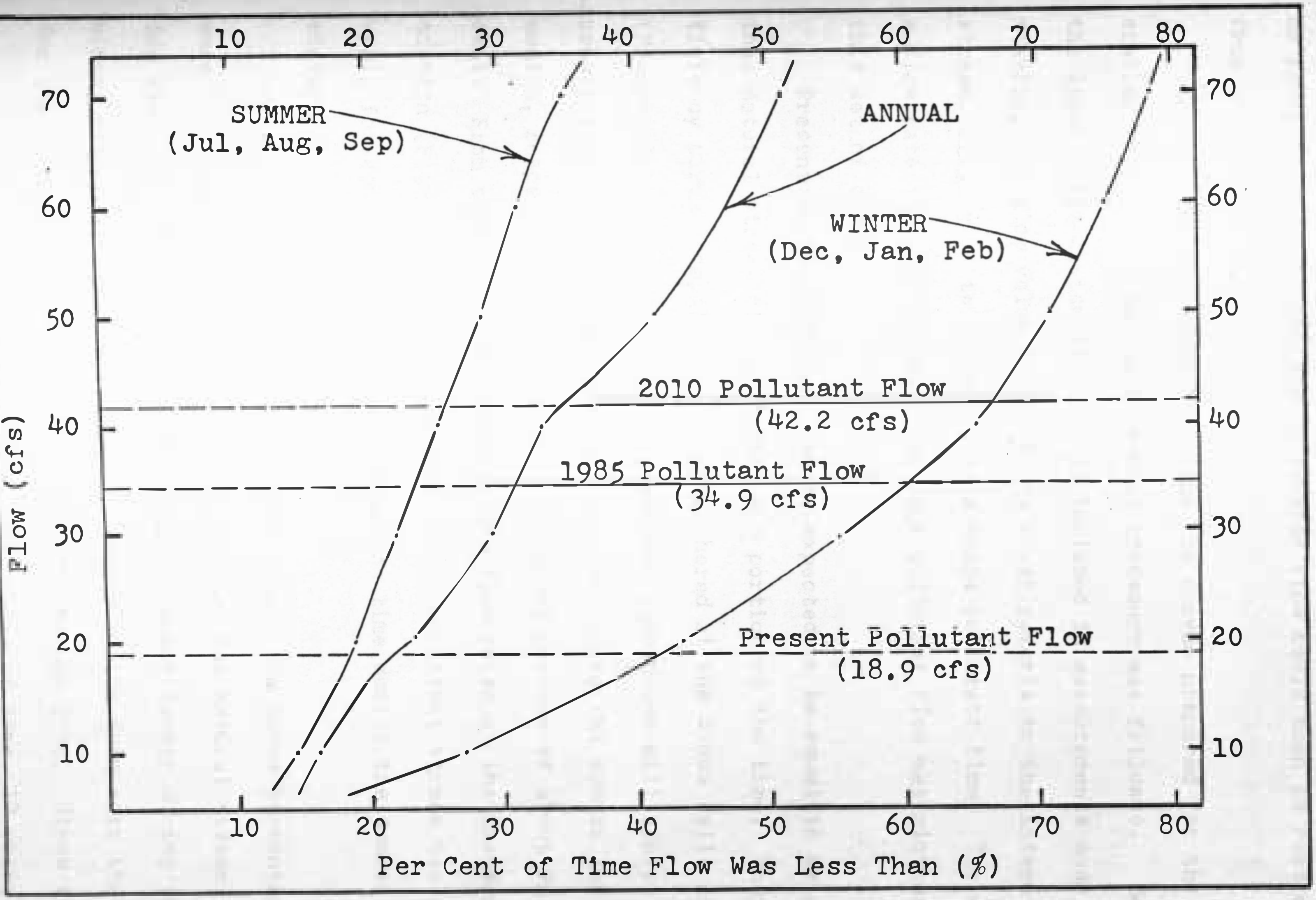

Figure 3. Deficiency Curves, Big Sioux River at Sioux Falls, South Dakota, 1944-1960, with Present and Future Pollutant Flows.

be equal to or less than the wastewater flow could then be read directly from the graph.

To obtain this information from the curves prepared for the Brandon station (Figure 4), the same general procedure was followed. Because the Sioux Falls wastewater flow is included in measurements made at this station, the flow value at which the river reverts to the intermittent stream category is twice the daily average pollutant flow. Therefore, a flow rate of twice the daily average pollutant flow was plotted on this set of curves.

Present wastewater flows can be expected to be equal to or greater than natural stream flow a significant portion of the time. The deficiency curves compiled from data gathered at the Sioux Falls station (Figure 3) indicate that the intermittent stream use will apply approximately 18 and 42 per cent of the time during the summer and winter months, respectively, with an overall annual average of about 22 per cent. From the curves prepared for the flow rates at the Brandon station (Figure 4), it appears that the intermittent stream use should apply for about 16 and 65 per cent of the time during the summer and winter periods, respectively.

Since the pollutant flows used to obtain the above percentages were the same in both cases, it appears that the natural stream flows for the years of 1944 through 1960 were somewhat larger during the winter months and smaller during the summer months than were the flows for the same months during the years 1959 through 1966. Since the curves shown in Figure 3 cover a longer period of time (17 years as

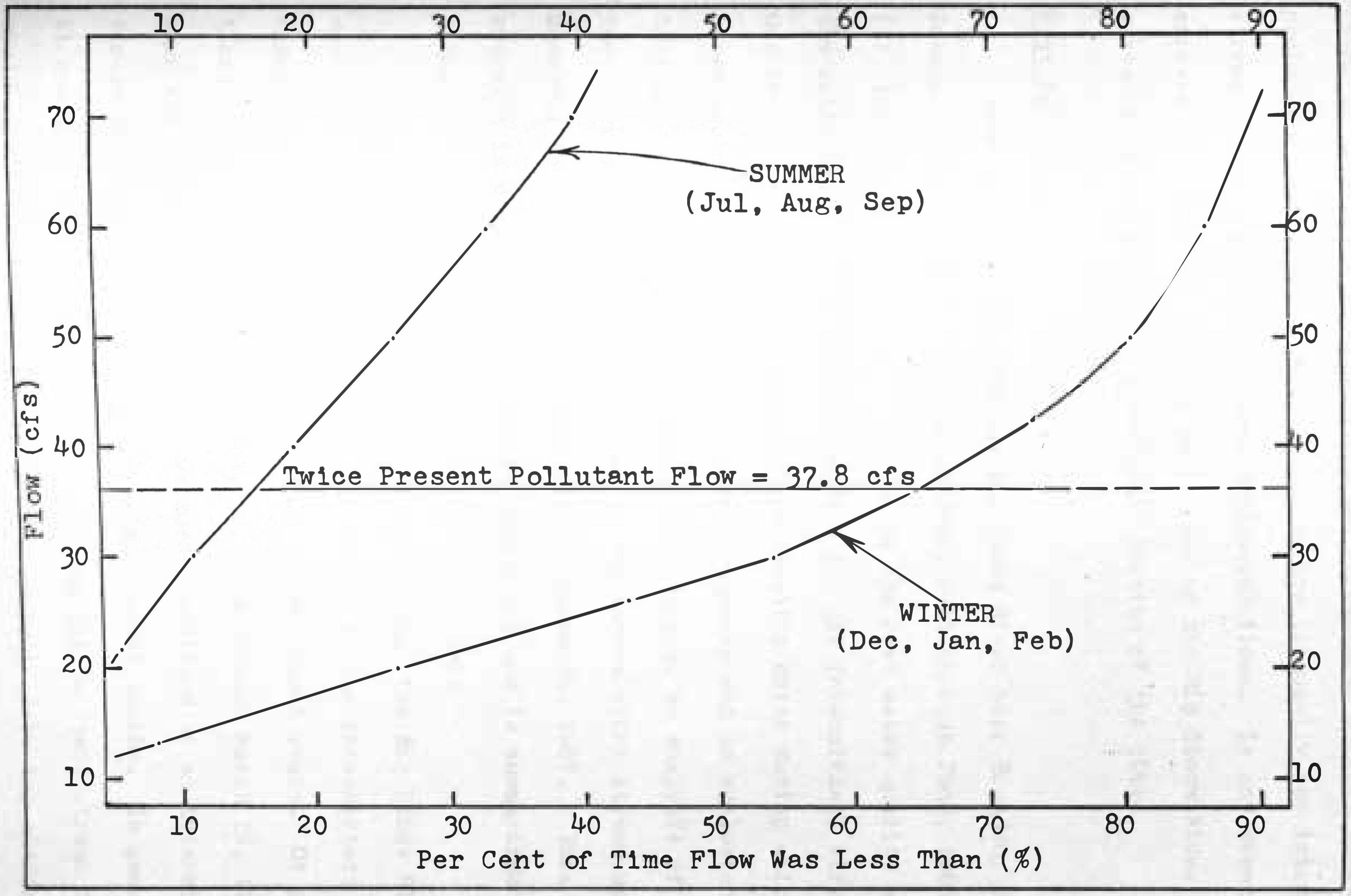

Figure 4. Deficiency Curves, Big Sioux River at Brandon, South Dakota, (1959-1966), with Twice Present Pollutant Flow.

compared to 8 years for Figure 4), the percentages derived therefrom probably give the better estimate as to how frequently the intermittent stream use will apply at present wastewater flows. In any event, it appears that this use will be applicable to the Big Sioux River downstream from Sioux Falls a significant portion of the time.

Past Water Quality

Water quality data for the Big Sioux River near Brandon, South Dakota is available for the period June, 1961 through June, 1966 (11, 12). However, in order to compare the past water quality with the criteria specified in the standard for the intermittent stream use it was necessary to determine the specific dates during which the river would have probably been in this category and to evaluate the test data obtained on those dates. Accordingly, an analysis of when the river would probably have been in the intermittent stream use was made for the period June 1, 1961 through March 30, 1967. This analysis is presented in detail in Appendix B and is summarized in tabular and graphical forms in Table 2 and Figure 5.

From the above analysis, it appeared that the Big Sioux River downstream from Sioux Falls would have been in the intermittent stream category for extended periods of time during recent years. Of particular note is the period of July 30, 1964 through March 19, 1965 when the river would probably have been classified as an intermittent stream for 233 consecutive days or almost eight months. In general, it can also be seen from Figure 5 that the intermittent stream use would probably have been in effect from approximately the middle of

Table 2. Time Periods that the Big Sioux River below Sioux Falls would have been in Intermittent Stream Use Category (June 1, 1961 - March 31, 1967)

Water Year (Oct 1 to Sep 30)	Dates of Intermittent Stream Use (From -- To)	Days of Intermittent Stream Use	Summer Days (Jul, Aug, & Sep)	Winter Days (Dec, Jan, & Feb)	Total Days
1961	Sep 11-Sep 26	16	16	--	16
1962	Oct 5 - Nov 4 Dec 10-Mar 27	31 108	0	81	139
1963	Jan 7 - Mar 7	60	0	53	60
1964	Dec 18-Mar 11 Jul 30-Sep 30	85 63	63	74	148
1965	Oct 1 - Mar 19	170	0	90	170
1966	Jan 14 -Feb 3 Aug 10-Aug 19	21 10	10	21	31
1967	Nov 9 -Nov 19 Dec 14-Dec 22 Dec 25-Mar 7	11 9 73	0	75	86

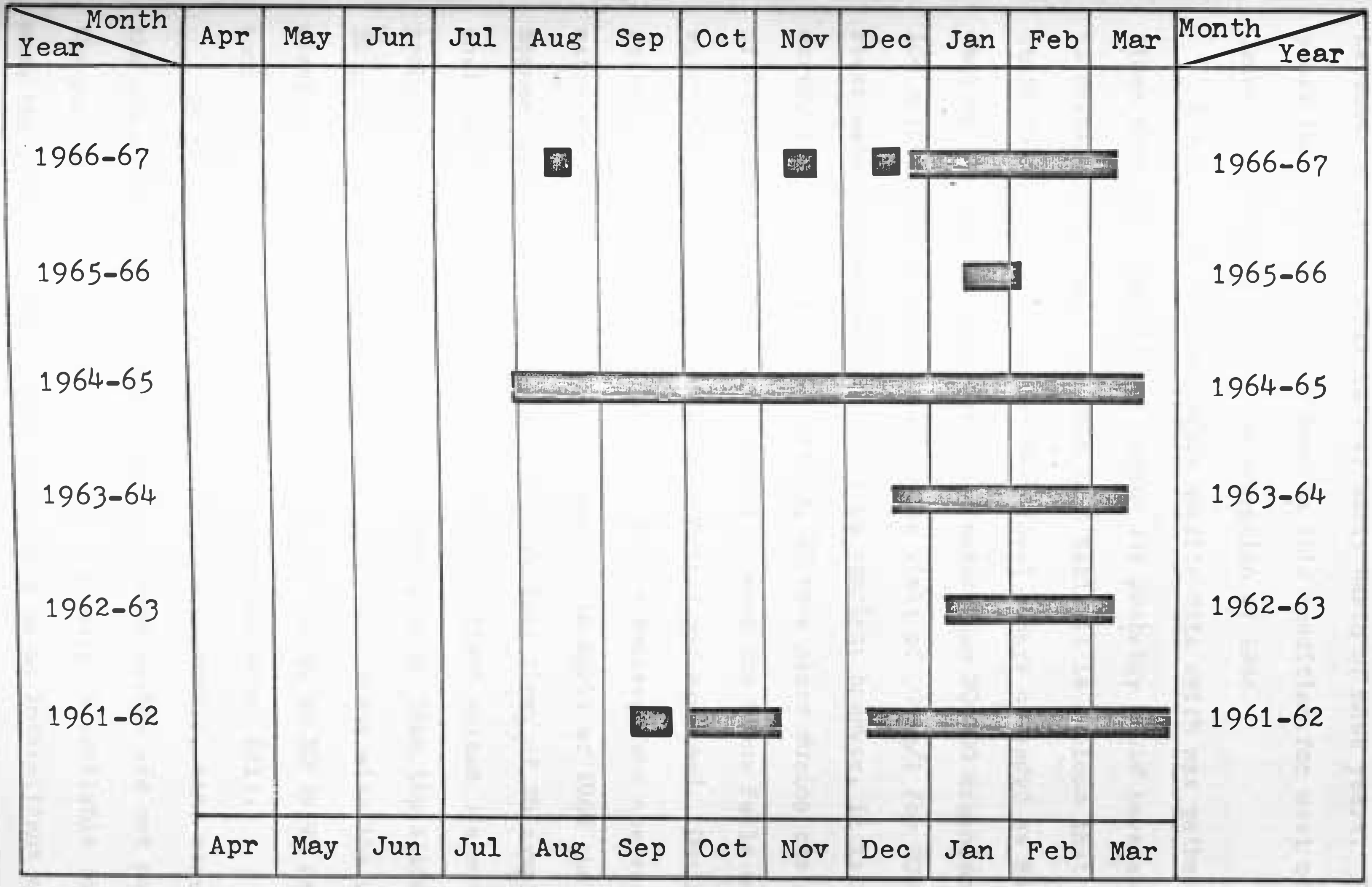

Figure 5. Periods during which Big Sioux River below Sioux Falls would have been in Intermittent Stream Category, (June, 1961-March, 1967)

December until late February or early March of most years. For all years the river would have been in this condition for most of January and February with the exception of 1966.

A summary of the available quality data which was gathered at times when the intermittent stream use probably would have applied is presented in Table 3. From this table it is obvious that the limit for coliform organisms was almost always exceeded as 86.7 per cent of the samples gave results greater than 20,000 organisms per 100 milliliters of river water. The limit of 30 mg/l for BOD of the river water was exceeded on 24 of 55 samples; however, it is noteworthy that of these 24 violations, 20 took place during the period of September, 1961 through March, 1962 when the Sioux Falls wastewater treatment plant was being renovated and expanded. During this period, all or portions of the plant were bypassed and the wastewater was not receiving full treatment. In April of 1962 the plant became fully operational (11) and since that time, of 35 samples analyzed for BOD at times when the intermittent stream use would probably have applied, only 4 have been greater than the allowable 30 mg/l. It has also been reported that concurrent with the completion of improvements to the treatment plant, an 80 to 90 per cent reduction in BOD of the river water was noted (11).

Of 57 samples on which pH tests were performed, none were outside the allowable range. Analyses for suspended solids are not part of the routine sampling program, and no test data is available for times when the river would have been classified as an intermittent stream.

Table 3. Past Water Quality of the Big Sioux River at Brandon, South Dakota Intermittent Stream Use Category (June 15, 1961 - June 22, 1966)

Parameter	Limit	Number of Samples	Number of Times Exceeded	Per Cent of Time Exceeded (%)
Coliform Organisms	20,000 per 100 ml	53	46	86.7
Biochemical Oxygen Demand	30 mg/l	55	24	43.6
pH	6.0-9.5	57	0	0.0
Suspended Solids	30 mg/l	No Test Data Available		

Although suspended solids analyses are not routinely performed, it has been reported that the mean suspended solids level of the Big Sioux River below Sioux Falls is in the range of 81 to 400 mg/l (10-6). From an additional series of ten tests performed from April 5 through July 19, 1967, the average suspended solids concentration of the river water at Brandon was 78.7 mg/l. Test results ranged from a low of 30 to a high of 164 mg/l (13). During 1964, 1965 and 1966 the average suspended solids content of the effluent from the Sioux Falls treatment plant was 38, 31, and 26 mg/l, respectively (3). It was interesting to note that these values have been, in general, considerably lower than those which have been found in the river below Sioux Falls.

It must also be pointed out that there have been extended periods in the past when the Big Sioux River flow was essentially all wastewater from Sioux Falls. One such period was from January 28 to February 26, 1965 when the river flow at Brandon was 12 cfs, or lower, for 22 of 30 consecutive days (4). During this period, the suspended solids content of the treatment plant effluent was greater than 30 mg/l on 27 days and a maximum value of 137 mg/l was recorded on February 19, 1965 (3). Under these flow conditions, it appears likely that suspended solids levels in the river water would also be above 30 mg/l since no dilution was being provided. It does appear then, that if this limit is not to be exceeded in the river water at times of extremely low flow, the suspended solids content of the plant effluent should also not exceed 30 mg/l as little dilution may be available. In the past, this low level has not always been achieved.

Frequency of Occurrence at Future Wastewater Flows

This portion of the evaluation was carried out using the same general techniques as were utilized for the analysis at present wastewater flows, except that estimates of future wastewater discharges were required. Future flows to the Sioux Falls wastewater treatment plant have been estimated at 20.06 and 25.73 MGD for the years of 1985 and 2010 respectively (7). Adding the 2.5 MGD of condenser water from John Morrell and Company gave estimated total wastewater flows to the Big Sioux River of 22.56 and 28.23 MGD

(34.9 and 42.2 cfs). The same 2.5 MGD condenser water figure was used since the "operation carried on at John Morrell and Co. is not expected to change significantly in the future" (7-14).

These values for estimated future flows were then plotted on the deficiency curves (Figure 3) which were prepared from data gathered at the Sioux Falls gaging station. The curves derived from the data gathered for flow rates near Brandon were not usable for this analysis because the wastewater flows from Sioux Falls are included in these measurements. As the wastewater flows increase, the river flow at Brandon will also increase and these higher flow rates will result in altered deficiency curves.

It is readily apparent from the plots of future wastewater flows on Figure 3 that the intermittent stream use will become more predominant in future years unless supplementary dilution water can be made available. From about 18 per cent of the time during the summer months at present wastewater flows, it appears that this use will increase in frequency during the summer months to approximately 23 and 26 per cent by the years 1985 and 2010, respectively. For the winter months, an increase to about 61 and 67 per cent is indicated for the same years with the annual average rising to about 31 and 35 per cent. After 1985 it appears that the river will probably be in this category approximately one fourth of the time during the summer months. This should be noted when evaluating the possibilities of using the river water for irrigation, fishing, boating, and general recreation.

FISH LIFE PROPAGATION USE CATEGORY

General

The fish life propagation use category was prescribed as a beneficial use for those waters thought to be capable of supporting a fish population. Since some fish are much more tolerant to adverse environmental conditions than others, waters designated for fish life propagation were further divided into five sub-categories reflecting the type of fish population each was deemed capable of supporting. The Big Sioux River downstream from Sioux Falls was classified as a "warm water marginal" fishing stream; the exact definition is quoted from the standards (1-16):

> "Lakes, streams and reservoirs in this category shall be suitable for supporting more tolerant species of fish with frequent stocking and intensive management. Principal species managed in these lakes include perch, northern pike and bullheads."

It is further stated in the standards that the water quality will be adequate to support all other aquatic life essential to the maintenance and propagation of fish life (1-18). It is also noted in the standards that since most of the rivers in South Dakota are quite erratic in seasonal flow variations, many are probably incapable of supporting fish life except at periods of higher flow, and that as these streams begin to experience low flows most will be placed in the intermittent stream use category (1-3). As has already been shown, the intermittent stream use will probably be applicable to the Big Sioux River downstream from Sioux Falls a significant portion of the time, especially during the winter months.

Past Water Quality

The quality criteria and test results of samples analyzed for the various parameters specified for this category are summarized in Table 4. In accordance with the provisions of the standards, the only test results reflected in Table 4 are those for samples taken at Brandon during times when the river would not have been classified as an intermittent stream.

Of the samples analyzed for pH and temperature, none were outside the allowable limits. Of 146 samples analyzed for dissolved oxygen, 12 (8.3%) gave results less than the required 2.0 mg/l. Again however, it must be noted that all of these violations took place in late 1961 when the wastewater treatment plant was being totally or partially bypassed. Since April, 1962 when the plant became fully operational, of 125 samples analyzed for dissolved oxygen, all gave results of greater than 2.0 mg/l. Further, of these 125 samples, 113 gave results of greater than 4.0 mg/l and 105 had dissolved oxygen contents of greater than 5.0 mg/l. The mean dissolved oxygen content of the river water during this period was 7.6 mg/l (11, 12).

For three of the parameters for which limits are specified in this category (suspended solids, hydrogen sulfide and cyanides) no test data is available. Despite this, some judgments are possible as to whether or not maintenance of the specified water quality is apt to present problems.

It has been previously noted that the Sioux Falls wastewater treatment plant does achieve a high reduction of suspended solids

Table 4. Quality Criteria and Past Water Quality of the Big Sioux River at Brandon, South Dakota
Fish Life Propagation Use Category
(June 15, 1961 - June 22, 1966)

Parameter	Limit	Frequency Code	Number of Samples	Number of Times Exceeded	Per Cent of Time Exceeded (%)
Dissolved Oxygen (Greater Than)	2.0 mg/l	a	146	12	8.3
pH	6.0 - 9.3	a	145	0	0.0
Temperature	93° F	a	145	0	0.0
Suspended Solids	150 mg/l	a	No Test Data Available		-
Hydrogen Sulfide	1.0 mg/l	a	No Test Data Available		-
Cyanides	0.05 mg/l	a	No Test Data Available		-

as the plant effluent normally averages about 30 mg/l; the maximum monthly average during the years of 1964 through 1966 was 70 mg/l which was recorded in February of 1965 (3). It appears then, that if the limit of 150 mg/l is exceeded it will be due to the effect of natural runoff or other sources rather than as a result of the treated wastewater discharged to the river at Sioux Falls. In a series of ten analyses made for suspended solids from samples taken from the Big Sioux River at Brandon from April 5 through July 19, 1967, one value of 164 mg/l was recorded on June 28. All others were less than 150 mg/l and the mean was 78.7 mg/l (13). On June 28, river flow was 912 cfs (4) so it is apparent that most of the flow was runoff from the drainage basin. It appears then, that suspended solids concentrations of greater than 150 mg/l may be recorded at times of high river flow.

At present, there is no known industrial activity in or around Sioux Falls which could be expected to discharge cyanides. This absence of possible cyanide contributors plus the fact that no problems have ever been encountered at the treatment plant with toxicity to micro-organisms are indicative that cyanides are not contained in the wastes which are discharged to the Big Sioux River. Therefore, keeping the cyanide level below the specified limit of 0.05 mg/l should present no problems.

The other parameter in this category for which no test data is available is hydrogen sulfide. This gas can be generated in water by the reduction of the sulfate ion to the sulfide form and a subsequent combination of hydrogen and sulfide ions. These reactions will only take place when free dissolved oxygen or nitrate ions are not present to serve as a source of oxygen (17-321). The Big Sioux River below Sioux Falls generally has a sulfate content of over 200 mg/l (11, 12). Thus, hydrogen sulfide could be produced in the river if the dissolved oxygen level should ever be at or close to zero. However, at all times since April, 1962 when the fish life propagation use would have been applicable, the dissolved oxygen of the river at Brandon has always been above 2.0 mg/l. This would have prevented the formation of hydrogen sulfide; therefore, compliance with the limit of 1.0 mg/l should not be a problem under present conditions.

LIMITED CONTACT RECREATION USE CATEGORY

General

All waters within the state of South Dakota which were deemed suitable for recreation uses were classified into one of two recreational sub-categories: Immersion Sports or Limited Contact Recreation. Those waters placed in the first sub-category are to be suitable for all water based recreation which requires complete bodily immersion, such as swimming, water skiing or skin diving. The second sub-category of waters is to be suitable for other water related recreation not involving bodily immersion such as fishing, boating, sailing, and picnicking (1-20). The Big Sioux River downstream from Sioux Falls was placed in the second sub-category of limited contact recreation (1-36).

The criteria for this category are to apply only during the summer recreation season unless the waters are also used extensively for winter recreation. In the latter case, the criteria are to apply all year round (1-20). It is not believed that the Big Sioux River downstream from Sioux Falls is used extensively for winter recreation. For the purposes of this study, the recreation season was taken as extending from May 1 through September 30 of each year.

Past Water Quality

The quality criteria and results of tests made for the two parameters specified for this use category are summarized in Table 5. All samples from which the data was compiled were taken during the periods

Table 5. Quality Criteria and Past Water Quality of the Big Sioux River at Brandon, South Dakota
Limited Contact Recreation Use Category
(May 1, 1961 - September 30, 1966)

Parameter	Limit	Frequency Code	Number of Samples	Number of Times Exceeded	Per Cent of Time Exceeded (%)
Coliform Organisms	Not to exceed a MPN or MF of 5,000 per 100 ml as a monthly average; nor to exceed this value in more than 20% of the samples examined in any one month; nor to exceed 10,000 per 100 ml on any one day during the recreation season.		78	77	98.7
Dissolved Oxygen	Greater than 2.0 mg/l.	a	75	11	14.7

of May 1 through September 30 of the years 1961 through 1966. Again, no data was included from tests made while the river would probably have been in the intermittent stream use category.

For this use also, as was the case for past water quality of the river while in the intermittent stream category, coliform counts were greater than allowable almost without exception, as 98.7 per cent of the tests performed gave results of greater than 5,000 organisms per 100 ml. In most cases, the actual counts recorded were far in excess of this and several were as high as several million per 100 ml (11, 12).

Of the 75 samples analyzed for dissolved oxygen content, 11 gave results less than the required 2.0 mg/l. Again however, it should be emphasized that all of these violations took place during the recreation season of 1961 when the Sioux Falls treatment plant was being expanded and the wastewater was not being completely treated. During times when the limited contact recreation use would have been applicable during the years of 1962 through 1966, all samples analyzed contained greater than 2.0 mg/l of dissolved oxygen. In fact, of the 61 samples analyzed beginning with the recreation season of 1962, 46 gave results of greater than 4.0 mg/l and 40 had dissolved oxygen concentrations of greater than 5.0 mg/l. The mean dissolved oxygen level during these times was 6.1 mg/l. In general, the dissolved oxygen content was two to four mg/l higher than required during the recreation season (11, 12).

WILDLIFE PROPAGATION AND STOCK WATERING USE CATEGORY

General

This beneficial use was assigned to all lakes, rivers and streams in South Dakota because all are used for either wildlife propagation or stock watering to a limited degree (1-6). The quality criteria specified in the standards are designed to maintain the waters as a suitable habitat for aquatic or semi-aquatic wild animals and fowl, and as a source of water for domestic and wild animals and fowl. It is further stated in the standards that, "No pollution shall be permitted to enter waters in this category which will produce inhibited growth, physical impairment or injurious effects on wild or domestic animals and fowl normally inhabiting or using the water" (1-21).

Past Water Quality

The quality criteria and test results of samples analyzed for this category are presented in Table 6. Here also, no test data was included from samples taken when the intermittent stream use would have been in effect.

From Table 6 it can be seen that for the first three parameters listed, none of the tests conducted gave results which would have been in violation of the standards. At all times the concentrations were well within the allowable limits. The maximum value for alkalinity was 480 mg/l (most values were in the 150 - 300 mg/l range). The high for total dissolved solids was 1056 mg/l (most values were below 700 mg/l). The pH ranged from 6.2 to 8.7. Of these pH values,

Table 6. Quality Criteria and Past Water Quality of the Big Sioux River at Brandon, South Dakota
Wildlife Propagation and Stock Watering Use Category
(June 15, 1961 - June 22, 1966)

Parameter	Limit	Frequency Code	Number of Samples	Number of Times Exceeded	Per Cent of Time Exceeded (%)
Alkalinity (Total as $CaCO_3$)	750 mg/l	c	145	0	0.0
Total Dis-solved Solids	2500 mg/l	c	141	0	0.0
pH	6.0-9.5	a	145	0	0.0
Electrical Conductivity	4000 umhos per cm @ 25^{o}C	c	No Test Data Available		---
Nitrates (as NO_3)	50 mg/l	a	No Test Data Available		---

6.2 was recorded only once in the 145 samples; all others were 7.2 or above. In general, the pH was in the range of from 7.2 to 8.0 (11, 12).

For two of the parameters (electrical conductivity and nitrates) for which limiting concentrations are specified in this category, analyses are not routinely performed on samples taken at Brandon. Here again however, it is possible to make some judgments as to probable concentrations from the limited or related data which is available.

Electrical conductivity of a water measures essentially the same pollutional characteristic as total dissolved solids since the ability of a water to conduct an electrical current is due to the ionization of dissolved chemical salts. In general, the electrical conductivity is proportional to the total dissolved solids content and this test is often used in fish and irrigation studies as a quick method for determining the ion concentration in a water. It has normally been found that values of electrical conductivity (expressed as micromhos per centimeter at 25° C) multiplied by 0.65 are approximately equal to the concentrations of dissolved salts in mg/l (18-273).

Since the maximum value recorded for dissolved solids during periods when the wildlife propagation and stock watering use category would have been applicable was 1056 mg/l, it appears that the maximum value for electrical conductivity would have been approximately 1056/0.65 or 1635 micromhos per centimeter at 25° C. This is well within the prescribed limit. It has also been reported that the normal range for electrical conductivity of the Big Sioux River water is from 200 to 800 micromhos per centimeter at 25° C (1-4). It appears then that this limit has probably not been exceeded under past conditions.

It has been reported that the Big Sioux River downstream from Sioux Falls is high in nitrates (1-4). That this should be so is not surprising when the myriad of possible nitrogen sources along the river is taken into consideration. In addition to the domestic wastewater treated at the Sioux Falls treatment plant, approximately 4.1 MGD of meat processing waste is also treated (7-14). Both of these wastes are high in nitrogen and while no figures on nitrogen removal efficiency are available, in general only from 20 to 50% is removed by biological treatment (19-348). In addition to these sources, significant amounts of nitrogen are also normally found in surface and sub-surface drainage from crop land, feed lots, and in irrigation return flows. These additional possible sources are also found along the Big Sioux River. While it is difficult to estimate the amount of nitrogen which results, it can be expected to be substantial (19-351).

Data as to the nitrite (NO_2) plus nitrate (NO_3) concentrations of the Big Sioux River water at Brandon is available from a series of 13 tests performed between December 9, 1964 and November 2, 1966 (20). This data was gathered from samples which were taken approximately monthly from December, 1964 through April, 1965 and from

August, 1965 through April, 1966 plus one sample which was taken on November 2, 1966. Of the values recorded, the maximum was 9.0 mg/l (expressed as nitrogen) on February 2, 1966. This is equivalent to approximately 40 mg/l expressed as nitrate ion. Of the other 12 values, only one was greater than 5.0 mg/l. It should also be noted that these samples were taken at times during which the lowest flows of the year are normally recorded (4, 5, 6). This was the case in 1964, 1965, and 1966 so it is probable that the most severe conditions for high nitrate concentrations were noted. Based upon this data, it does not seem likely that the limit of 50 mg/l has been exceeded in the past.

Some further nitrogen data is also available from a limited number of tests which were performed from June 14 through July 19, 1967 (13). In this series of analyses, tests were performed for the organic, ammonia, nitrite, and nitrate forms of nitrogen from samples taken a short distance upstream from the outfall of the wastewater treatment plant, at the highway 38A bridge north of Sioux Falls and at Brandon. (See Figures 1 and 2 for the locations of the sampling points). The results of these tests are presented in Table 7. While nitrate concentrations were well below the allowable 50 mg/l at all sampling points for all tests performed, it is noteworthy that nitrate levels were actually lower in most cases at Brandon than upstream from Sioux Falls; total nitrogen concentrations were higher, however, at Brandon than at the other sampling points.

Table 7. Nitrogen Analyses - Big Sioux River
(June 14, 1967 - July 19,1967)

Date of Sample	Location of Sample Point	Ammonia Nitrogen (mg/l as N)	Organic Nitrogen (mg/l as N)	Nitrite Nitrogen (mg/l as N)	Nitrate Nitrogen (mg/l as N)	Nitrate Nitrogen (mg/l as NO_3)
	Highway 38A	0.4	1.4	0.056	2.2	9.75
June 14	Above Plant	1.2	2.6	0.074	1.6	7.08
	Brandon	5.0	2.8	0.205	2.0	8.85
	Highway 38A	0.2	0.0	0.032	1.3	5.75
June 28	Above Plant	1.2	2.4	0.080	1.6	7.08
	Brandon	0.4	2.8	0.108	1.3	5.75
	Highway 38A	0.4	2.0	0.01	0.7	3.10
July 19	Above Plant	0.8	2.6	0.008	0.0	0.00
	Brandon	1.4	2.6	0.25	0.6	2.66

It is apparent that nitrogen is entering the river from some other source(s) and the Sioux Falls wastewater is not the only, nor perhaps even the major contributor.

IRRIGATION USE CATEGORY

General

The irrigation beneficial use category was assigned to waters in South Dakota which were being used or showed potential for development of irrigation projects (1-7). At present, several irrigation projects are in operation and are using water from the Big Sioux River (14-8). It also seems probable that such use is likely to increase in the future as the benefits of irrigation are made more apparent to the South Dakota farmer.

Waters for which the irrigation beneficial use category has been assigned are to be suitable for irrigating farm and ranch lands, gardens and recreation areas (1-22). It is also stated in the standards that since the suitability of a water for irrigation is influenced to a large degree by the type of soil to be irrigated, the quality criteria specified for this category are upper limits only for the concentrations of the various parameters. The actual required water quality is to be established by the South Dakota Committee on Water Pollution on an individual basis after results of soil tests and other pertinent data have been compiled upon which a decision can be made (1-22). For this study, the upper limits for concentrations were used as the allowable values.

The quality criteria for the irrigation use are applicable during the irrigation season and not at other times of the year (1-22). In South Dakota, the irrigation season normally extends from about May 1 through September 30 of each year[4]. Data presented in this section are from analyses of samples taken from the Big Sioux River at Brandon during these months from 1961 through 1966 excluding those times when the intermittent stream use would probably have applied.

Several conditions must also be made clear as to under what conditions certain portions of the quality criteria specified for this use are to apply. First of all, the coliform limits are applicable only if root crops or recreation areas are to be irrigated (1-22). Also, since total dissolved solids and electrical conductivity are measures of essentially the same pollutional characteristic, it has been left to the discretion of the committee as to which shall be used in each case. The same is true with respect to the limits specified for sodium adsorption ratio (SAR) and soluble sodium percentage. Since both of these tests are measures of the salinity hazard of a water for irrigation, it has also been left to the committee to decide which parameter shall be used in each case (1-22).

Past Water Quality

The quality criteria and test results of samples analyzed for the parameters specified for this category are presented in Table 8. From this table, it can be seen that the limit for coliform organisms was again exceeded almost without exception as 98.7 per cent of the analyses gave results of greater than the allowable 5,000 organisms

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[4]Personal correspondence with personnel of the Bureau of Reclamation, Huron, South Dakota.

Table 8. Quality Criteria and Past Water Quality of the Big Sioux River at Brandon, South Dakota
Irrigation Use Category
(June 15, 1961 - June 22, 1966)

Parameter	Limit	Frequency Code	Number of Samples	Number of Times Exceeded	Per Cent of Time Exceeded (%)
Coliform Organisms	The MPN of MF shall not exceed 5000/100 ml as a monthly average nor exceed 10,000/100 ml in any one sample. (Root crops and recreation)	-	78	77	98.7
Total Dissolved Solids	700 - 1500 mg/l	d	70	0	0.0
Electrical Conductivity	1000 - 2500 umhos/cm @ 25°C	d	No Test Data Available		---
Sodium Adsorption Ratio (a)	10 - 26	d	No Test Data Available		---
Soluble Sodium Percentage (b)	30 - 70%	d	No Test Data Available		---

(a) SAR = $Na/\left[\frac{1}{2}(Ca+Mg)\right]^{\frac{1}{2}}$ where Na, Ca, and Mg are in milliequivalents/liter
(b) Na% = 100Na/(Ca+Na+Mg+K) where Na, Ca, K, and Mg are in millequivalents/liter

per 100 milliliters (11, 12). This is the same condition as was found when investigating the other use categories for which a coliform limit was specified. Dissolved solids concentrations, the one other specified parameter for which test data is available, was analyzed for from 70 samples. Of these, none gave results of greater than the specified upper limit of 1500 mg/l; only two values were recorded in excess of 900 mg/l. Fifteen of the tests did give results of more than the specified lower limit of 700 mg/l (11, 12).

For the other parameters for which limiting concentrations are specified for this use category, analyses are not routinely performed upon samples taken from the river at Brandon. Again however, either limited or related data is available from which some judgments can be made.

As explained previously, the parameters of electrical conductivity and total dissolved solids are closely related (18-273). The highest value recorded for total dissolved solids during times when the irrigation use would have been applicable to the river was 1056 mg/l (10). Therefore, using the same relationship as previously explained, the maximum value for electrical conductivity was probably about 1635 micromhos per centimeter at 25° C which is well within the upper limit (18-273).

It has been reported that the values for SAR and soluble sodium percentage of the Big Sioux River water at Sioux Falls normally range between 0.2 to 0.6 and 7 to 12% respectively (1-4). Both these ranges are well below the allowable limits of 10 to 26 and 30 to 70% which are specified in the standards. In a limited series of analyses made of seven samples taken from the river at Brandon and Sioux Falls from 1960 to 1967, the maximum value recorded for SAR was 5.6 on January 13, 1967. All other values were below 3.0 and five of the seven were less than 1.0 (21). It appears that the specified limits for SAR and soluble sodium percentage have not been exceeded in the past.

BENEFICIAL USES INCLUDING TIMES OF INTERMITTENT STREAM CLASSIFICATION

It has been demonstrated that the Big Sioux River downstream from Sioux Falls probably would have been in the intermittent stream category a significant portion of the time in past years and that the frequency of this use will probably increase in the future. It has also been demonstrated that this use would not have been confined to any one season of the year although it would have been more predominant during the winter months. Therefore, it appears logical that even though maintenance of quality criteria for other beneficial uses is not required by the standards at times when the intermittent stream use applies (1-5), the river will probably be used during these intermittent stream periods for other beneficial purposes. Accordingly, the water quality at all times of the year is of interest including periods when the intermittent stream use is in effect. A summary of this overall quality from June, 1961 through June, 1966 is presented in Table 9 for those parameters listed in the standards for which test data is available. In Table 9, data gathered from all weekly samples taken at Brandon is included. No allowance has been made for those times when the intermittent stream use would have applied. Only those quality criteria parameters for uses other than intermittent stream are reflected in the table.

The two parameters for which the limits were exceeded were dissolved oxygen (fish life propagation and limited contact recreation

Table 9. Overall Past Water Quality of the Big Sioux River at Brandon, South Dakota (June 15, 1961 - June 22, 1967)

Parameter	Limit	Frequency Code	Use*	Number of Samples	Number of Times Exceeded	Per Cent of Time Exceeded (%)
Dissolved Oxygen (Greater than)	2.0 mg/l	a	2e	204	32	15.7
	2.0 mg/l	a	3b	83	14	16.9
pH	6.0-9.3	a	2e	202	0	0.0
	6.0-9.5	a	4	202	0	0.0
Temperature	93^{o} F	a	2e	202	0	0.0
Coliform Organisms	5000/100ml	-	3b	87	85	97.6
	5000/100ml	-	5	87	85	97.6
Alkalinity (Total as $CaCO_3$)	750 mg/l	c	4	202	0	0.0
Total Dissolved Solids	2500 mg/l	c	4	198	0	0.0
	700-1500 mg/l	d	5	78	0	0.0

No test data available for cyanides, hydrogen sulfide, and suspended solids (use 2e), nitrates (use 4), electrical conductivity (uses 4 & 5), and SAR or per cent Na (use 5)

*Designation of uses: 2e - Fish Life; 3b - Recreation; 4 - Stock and Wildlife; 5 - Irrigation uses) and coliform organisms (limited contact recreation and irrigation uses). The other limits for pH, temperature, alkalinity, and total dissolved solids were not exceeded at any time between June, 1961 and June, 1966 (11, 12). It is noteworthy that this is the same situation as was found when the quality evaluations were made taking into consideration those times during which the river would have been in the intermittent stream use.

Of the 32 samples which gave dissolved oxygen results of less than the required 2.0 mg/l, it must again be noted that most were taken during late 1961 and the first three months of 1962 when the Sioux Falls wastewater treatment plant was being expanded and the wastes were not being completely treated (11). After March 14, 1962, 185 of 192 weekly samples taken from the river had dissolved oxygen concentrations of greater than 2.0 mg/l. If only those times when the limited contact recreation use would have been applicable are considered, the contrast is even more striking. Of 14 samples which had dissolved oxygen levels of less than 2.0 mg/l, 13 were taken during the recreation season of 1961 (11). Beginning with May of 1962, 66 of 67 samples tested during the recreation seasons have had greater than 2.0 mg/l of dissolved oxygen (11).

Several of the parameters for which limiting concentrations are specified in the standards are not routinely tested for from the weekly samples taken at Brandon. The previous discussions of these parameters are generally applicable to this section with the exception of hydrogen sulfide.

Hydrogen sulfide gas can only develop in waters in which no free dissolved oxygen or nitrate ions are present to serve as a source of oxygen for biochemical activities (17-321). From January 6, through February 24, 1965, (during a period of intermittent stream classification) of seven samples taken from the Big Sioux River at Brandon, two had zero dissolved oxygen and three others had less than 0.5 mg/l (12). Under these essentially anaerobic conditions, hydrogen sulfide could have developed in the river and possibly reached a level greater than the allowable 1.0 mg/l. Except for this period of about two months, free dissolved oxygen has been present in the Big Sioux River at Brandon continuously since March, 1961 (11, 12), (all other samples but one gave results of greater than 2.0 mg/l) and hydrogen sulfide probably would not have developed.

EFFECT OF RIVER FLOW ON WATER QUALITY

The Big Sioux River downstream from Sioux Falls does experience large seasonal variations in flow rate. For example, the average flow rate at Brandon for the month of January from 1961 through 1966 was 27.3 cfs; the mean flow for April during the same years was 1185 cfs (4, 6). Since the amount and type of wastewater which enters the river at Sioux Falls is relatively constant, it would appear logical that fluctuations in water quality would be observed along with such variation in the amounts of dilution water.

Another factor which could contribute to fluctuations in the water quality is the amount of polluting matter which enters the stream in natural runoff from the drainage basin. Because the characteristics of the drainage basin have not been completely defined, an unknown amount of natural impurities do enter the stream. At times of high flow or immediately after a sizable rainfall, this contribution would probably be significant; during periods of lower flow the amount of natural pollution should be smaller since less runoff enters the river.

Since April, 1962, when the wastewater treatment plant at Sioux Falls became fully operational, it has been shown that the only quality criteria (for which test data is available) which have not been maintained at all times at the Brandon sampling station were those for BOD (intermittent stream use) and coliform organisms (limited contact recreation, irrigation, and intermittent stream uses). Although not a requirement of the standards it has also been shown that during times of intermittent stream use, the dissolved oxygen concentration in the river water has been below the 2.0 mg/l specified for the fish life propagation and limited contact recreation categories (11, 12).

It is apparent that amount of river flow had little or no effect on coliform counts since these counts were higher than allowable almost without exception, even though flow varied widely over the sampling period (4, 5, 6, 11, 12).

Because BOD and dissolved oxygen concentrations in the river are greatly affected by the degree of treatment provided to the wastewater, only samples for the period after March, 1962 when the wastewater plant was fully operational were evaluated to determine the influence of the flow on these parameters.

Since April, 1962 the BOD of the river water at Brandon was recorded to be greater than the allowable value of 30 mg/l on five occasions during periods when the intermittent stream use probably would have applied. In addition, on seven occasions during periods when the intermittent stream use would have been in effect, dissolved oxygen levels of below 2.0 mg/l were found. Although the low dissolved oxygen readings would not have been in violation of the quality standards, it was felt that analysis of these occurrences could possibly lead to a correlation with river flow. The dates and river flows for those times when the BOD of the river was above 30 mg/l or the dissolved oxygen concentration was less than 2.0 mg/l are presented in Table 10.

Table 10. Dates and River Flows for which BOD Values of Greater than 30 mg/l or Dissolved Oxygen Levels of Less than 2.0 mg/l have been Recorded. Big Sioux River at Brandon, South Dakota (Intermittent Stream Use Only)

Parameter	Date	Value Recorded (mg/l)	River Flow (cfs)
Biochemical Oxygen Demand	1/30/63	32.0	22
	2/6/63	52.0	24
	1/13/65	37.0	13
	2/3/65	42.0	10
	3/17/65	32.0	350
Dissolved Oxygen	9/9/64	1.8	30
	1/6/65	0.4	16
	1/20/65	0.0	18
	1/27/65	0.8	14
	2/3/65	0.0	10
	2/17/65	0.2	12
	2/24/65	0.4	10

Of the seven occasions when dissolved oxygen was less than 2.0 mg/l, six occurred during January and February of 1965 when river flow was less than 20 cfs. The other was an isolated instance on September 9, 1964 when river flow was 30 cfs. Of the five times during intermittent stream use when the BOD of the river water was greater than 30 mg/l, four occurred at flows of less than 25 cfs. The other sample was taken on a day when the river was in a period of transition from intermittent stream to the other beneficial uses and flow was 350 cfs.

Since the average daily wastewater flow from Sioux Falls at present is approximately 12.5 MGD (3) or 19.2 cfs, it is apparent that whenever the river flow at Brandon is 20 cfs or less, essentially all flow is wastewater. It is noteworthy that of the seven times at which dissolved oxygen concentrations were less than 2.0 mg/l, six took place when river flow was actually less than 20 cfs. For practical purposes then, essentially no dilution was being provided and all river flow was wastewater from Sioux Falls.

From April, 1962 through June, 1966 there were 554 days when the Big Sioux River downstream from Sioux Falls would have probably been in the intermittent stream category. Throughout these times, during only one period was stream flow at Brandon less than 20 cfs for an extended period of time. From November 29, 1964 through March 5, 1965 stream flow was less than 20 cfs for 98 consecutive days (4, 6). During this time only seven weekly samples were taken; six had dissolved oxygen contents of less than 2.0 mg/l. It is perhaps significant that at all times when river flow was greater than 20 cfs, dissolved oxygen levels at Brandon were also greater than 2.0 mg/l except for one instance in September, 1964.

The times during intermittent stream use when the BOD of the river water was greater than 30 mg/l do not fit any comparable flow pattern. Of the five occurrences, four took place at river flows of less than 25 cfs; conversely, on other days during January and February of 1965 when river flow was less than 20 cfs, BOD values were below 30 mg/l. However, when little or no dilution water is available, it is obvious that the BOD of the effluent from the wastewater treatment plant and that of the condenser water discharged from the meat packing plant should not exceed 30 mg/l if this limit is not to be exceeded in the river. In general, the BOD of the treatment plant effluent is between 20-30 mg/l and that of the condenser water ranges from 15-30 mg/l. These ranges have been exceeded in the past. At the low flows for which the intermittent stream use is applicable, it is not appropriate to make a judgment as to what effect dilution will have on the BOD of the river water since only very limited quality data is available for the Big Sioux River above Sioux Falls.

Since data as to dissolved oxygen levels of the river at flows of less than 20 cfs is only available for the cold winter months (See Table 10), it should not be concluded that at all flows of 20 cfs or greater during the warm weather months, dissolved oxygen concentrations at Brandon would also be above 2.0 mg/l. At higher temperatures the solubility of oxygen in the river would be less and the biological activity in the river would naturally be greater. Stabilization of organic matter would proceed at a much faster rate, and the oxygen demand rate would be correspondingly higher. This in turn would quicken the depletion of oxygen in the river and probably alter the dissolved oxygen concentrations to the point where the river could become anaerobic a short distance downstream from Sioux Falls. It has been demonstrated however, that for river flows above which the intermittent stream use does not apply, the amount and quality of dilution water in the river have been sufficient to maintain the dissolved oxygen concentration at Brandon at above 2.0 mg/l during all periods of the year.

EFFECT OF PRESENT WASTEWATER TREATMENT ON WATER QUALITY

The efficiency of the Sioux Falls wastewater treatment plant is very high in that approximately 98% removal of BOD is normally attained (3). This high efficiency is required because only an extremely limited amount of dilution water is available at times in the receiving stream. For extended periods in the past, flow in the receiving stream has been more than 50% wastewater from Sioux Falls. Another factor which necessitates a high degree of treatment is that the present BOD population equivalent of the wastewater which is treated is approximately 500,000. While the city has an actual population of only about 70,000, the approximately 4.0 MGD of industrial waste from John Morrell and Company is very high in BOD and averages about 2,000 mg/l. This in turn results in the large population equivalent. The domestic sewage flow of about 6.0 MGD averages approximately 300 mg/l of BOD (3).

Since the BOD of the raw wastes is high and wastewater flows do make up a considerable portion of river flow for extended periods, it appears logical that the degree of treatment provided would have a pronounced effect on the water quality of the Big Sioux River downstream from Sioux Falls. It has been reported that when the treatment plant did become fully operational in April, 1962, the BOD of the river water at Brandon was reduced 80-90% (11). That this was so can be seen from Figure 6 which is a plot of the variations in BOD of the river water at Brandon for the months of November through March during 1961-62, 1962-63 and 1964-65.

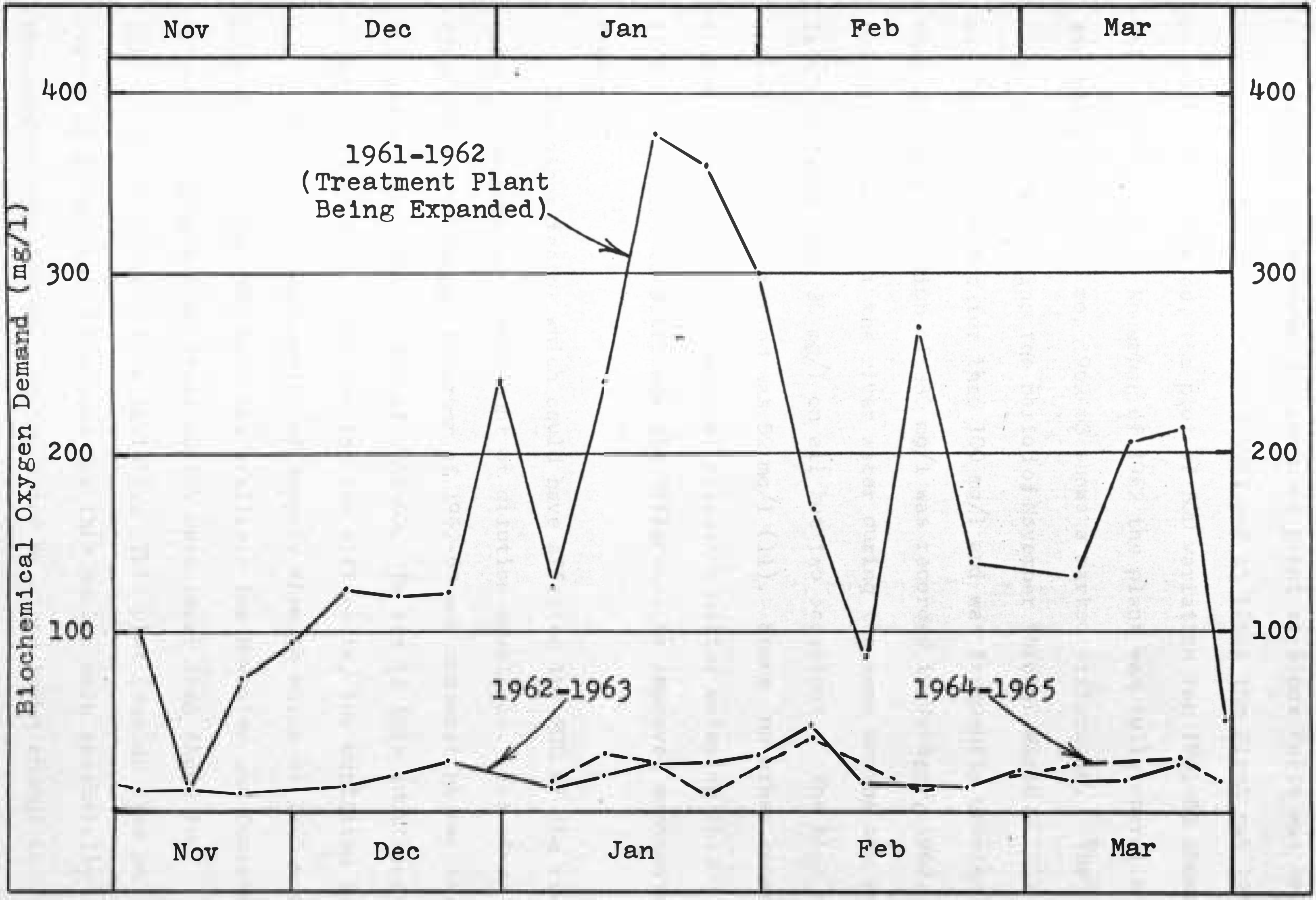

Figure 6. Variations of Biochemical Oxygen Demand,
Big Sioux River at Brandon, South Dakota,
(November - March of 1961-62, 1962-63, and 1964-65).

Because the wastewater treatment plant at Sioux Falls was being expanded during 1961 and early 1962 and at times the plant was totally or partially bypassed, the plot of BOD variation for 1961-62 shows this influence. By November of 1962 the plant was fully operational and the plot of BOD for 1962-63 shows a marked difference. The river water BOD during the period of November through March of 1961-62 was almost always greater than 100 mg/l and was frequently greater than 200 mg/l. A high of 380 mg/l was recorded in January, 1962. In contrast, the BOD of the river water during the same months one year later was less than 30 mg/l on all but two occasions. The high recorded during this period was 52 mg/l (11). Since no other known change occurred in the amount of polluting matter entering the stream, it seems logical to attribute the difference to improved wastewater treatment.

One other factor which could have affected the BOD of the river water at Brandon was the amount of dilution available. The river flow for March through November of 1962-63 was somewhat higher than for most of the same months of 1961-62. To see if this additional dilution could have accounted for the difference, the variation in BOD at Brandon for the months of January through March of 1965 was also plotted. (No BOD data was available for November and December of 1964.) Flows during these months were lower than those for 1962-63 as can be seen from Table 11. This plot (dashed line on Figure 6) shows that BOD values for this period were essentially the same as for 1962-63. Again, since no other known change in

Table 11. Monthly Average Flow Rates of Big Sioux River at Brandon, South Dakota (November-March of 1961-62, 1962-63, and 1964-65)

Month	Flow Rate (cfs) 1961-62	1962-63	1964-65
November	51.0	104.0	28.4
December	36.6	65.3	14.9
January	19.4	35.1	14.6
February	30.5	35.2	12.1
March	1342.0	257.0	98.1

amount of pollution entering the stream had occurred, it appears that the lower BOD values could probably be attributed to the improved treatment of Sioux Falls wastewater.

Figure 7 reveals that dissolved oxygen concentrations for the same periods were much less influenced by the improved treatment. This plot showed variations which seemed to follow the same general pattern as did flow rates in the river as can be seen by comparing the individual graphs with the mean flow rates given in Table 11. For instance dissolved oxygen levels and river flows in 1962-63 were generally higher than those found in 1961-62 and 1964-65. Figure 7 thus demonstrates that even with excellent treatment of the Sioux Falls wastewater (1962-63 and 1964-65), a certain amount of dilution water is required to maintain dissolved oxygen at suitable levels.

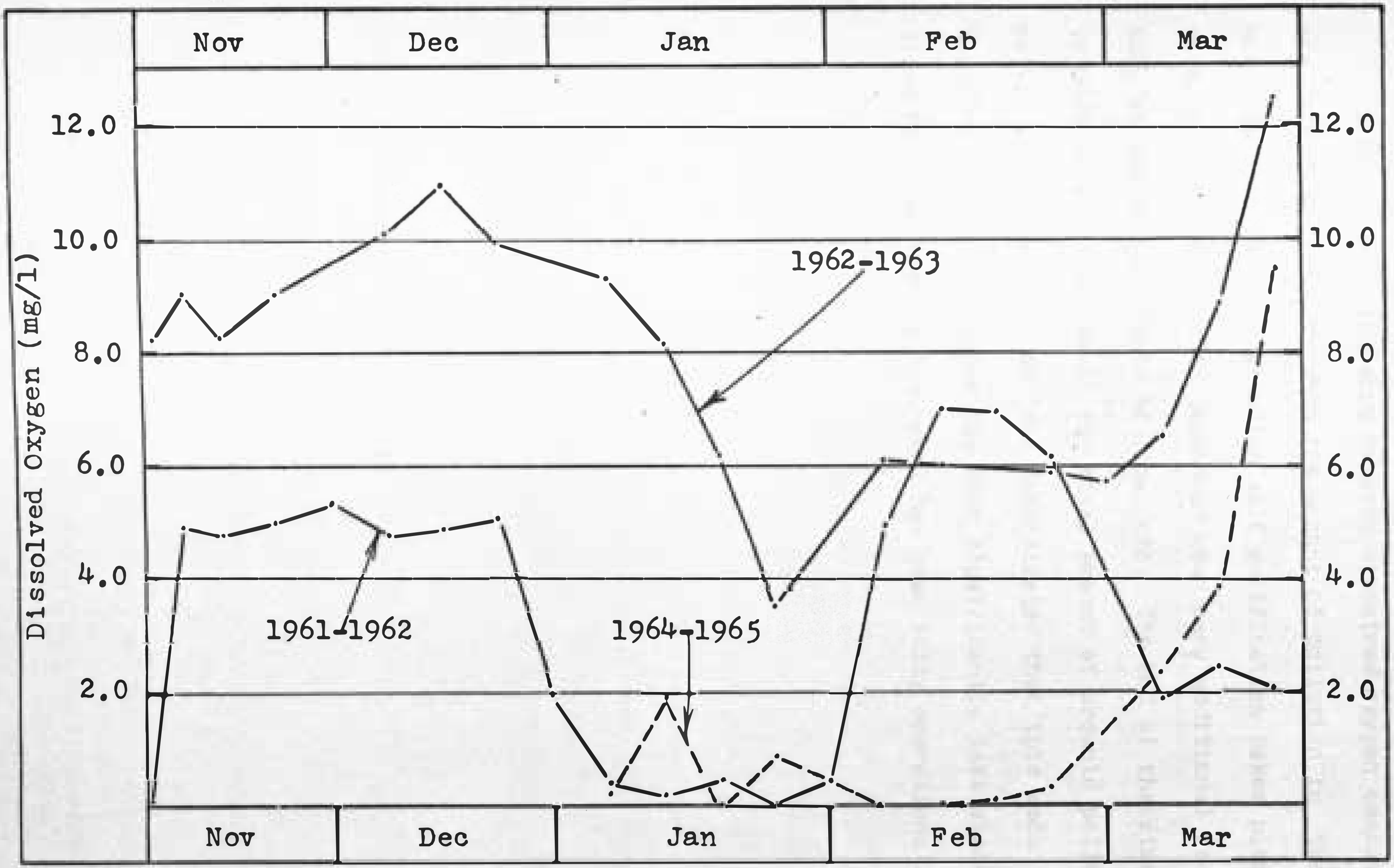

Figure 7. Variation of Dissolved Oxygen Levels,
Big Sioux River at Brandon, South Dakota,
(November - March of 1961-62, 1962-63, and 1964-65).

This is not surprising because dissolved oxygen concentrations are not only dependent upon the amount of pollution in the stream but also upon the rate at which self purification takes place. This rate, in turn, is further dependent upon many additional factors such as temperature, rate of flow, etc. The BOD of the river water is much more indicative of the total amount of organic polluting matter present and it has been demonstrated that this amount in the Big Sioux River at Brandon has been significantly less since the Sioux Falls wastewater treatment has been fully operational.

PROPOSED IMPOUNDMENTS

The Corps of Engineers presently has under study a possible system of flood control reservoirs along the main stem and some tributaries of the Big Sioux River. Of the five sites being considered, the three of interest to this study are located near Flandreau, South Dakota and on Skunk Creek upstream from Sioux Falls and near Canton, South Dakota which is downstream from Sioux Falls. (See location map, Figure 1)

Although the primary purpose of these reservoirs would be flood control, other benefits, such as recreational use or low flow augmentation for water quality control purposes, could also be possible. At present, no attempts have been made to determine the quantities of water required for the various possible beneficial uses although these uses have received some preliminary planning consideration. Analyses of possible discharges from the Canton site have indicated that reservoir capacity would be inadequate to provide downstream flow augmentation if, at the same time, sufficient flood control storage capacity were to be maintained; but, since this site is downstream from Sioux Falls, no additional dilution for the city's wastewater could be provided. Accordingly, the only use aspect considered in this study for the Canton site was recreation.

It has been demonstrated that whenever the intermittent stream use would not have applied to the Big Sioux River below Sioux Falls, dissolved oxygen levels in the river at Brandon have been more than the 2.0 mg/l required by the standards. On occasion, when the intermittent stream use would have applied, dissolved oxygen has been completely absent. Therefore, one obvious benefit would be that if sufficient discharges could be made from the upstream reservoirs, the Big Sioux River below Sioux Falls would never be classified as an intermittent stream. Based upon past data, it appears that if this were the case, the dissolved oxygen in the river at Brandon would always be greater than 2.0 mg/l and possible fish kills attributed to a lack of oxygen could be prevented.

At the present average wastewater flows of about 12.5 MGD, a constant flow in the river above Sioux Falls of approximately 20 cfs would be required to prevent intermittent stream use. With the addition of the Sioux Falls wastewater, a minimum flow of about 40 cfs would result below the city. However, on some days the volume of wastewater discharged to the river will be somewhat greater than the normal average, and larger reservoir discharges would be required. It has been estimated that the maximum daily flow to the Sioux Falls wastewater treatment plant which can be expected at present is 13.9 MGD (7-11). Adding to this flow the 2.5 MGD flow of condenser water from John Morrell and Company gives a probable maximum of total wastewater flow to the Big Sioux River of 16.4 MGD or 25.5 cfs. Therefore, if a flow rate from 20 to 25.5 cfs could be maintained in the Big Sioux River at Sioux Falls, it appears that at present wastewater flows, the river below the city would never be classified as an intermittent stream.

Estimates of future wastewater flows from the city of Sioux Falls have also been made for the years 1985 and 2010. Again including the 2.5 MGD flow of condenser water from the meat packing plant, these estimates for average and maximum daily flows are 20.06 and 28.15 MGD in 1985 (34.9 and 53.4 cfs) and 28.23 and 35.8 MGD in 2010 (42.2 and 55.4 cfs)(7-10). It is apparent then, that if the Big Sioux River is not to be classified as an intermittent stream at any time in future years, requirements for discharges from the proposed reservoirs will increase markedly.

The above discussion has presupposed that the reservoir water to be discharged would be of adequate quality to be suitable for downstream beneficial uses. Because quality degradation does occur in some impoundments, the water quality may not be satisfactory (16-18). The probable change in water quality in the proposed reservoirs along the Big Sioux River has not yet been evaluated. Before any attempt is made to use the reservoirs for downstream water quality control, an investigation should be conducted into the possibilities of eutrophication and what control measures might be required.

The other most probable beneficial use of the reservoirs, in addition to flood control, is to provide recreational facilities. If this use is to be feasible, the water quality in the reservoirs will have to be such that nuisance conditions such as extensive algal growths will not develop. In order for these growths to develop, it is required that certain nutrients, principally nitrogen and phosphorous, be present in the water. Although the exact nutrient requirements for all algae are not known, it is generally held that if nitrogen and phosphorous are present in amounts equal to or greater than certain critical levels, nuisance conditions can be expected to develop. Concentrations which have been widely quoted as being critical are 0.30 mg/l for inorganic nitrogen forms and 0.10 and 0.01 mg/l for organic and inorganic phosphorous respectively (15-9).

Weekly analyses for phosphates (PO_4) and ammonia form of nitrogen are made from samples of the Big Sioux River water taken at Brandon, South Dakota (11, 12). In general, the ammonia nitrogen content of the river water has been from 0.1 - 4.0 mg/l, although at times of low flow, concentrations in excess of 20 mg/l have been recorded. Phosphate concentrations have also normally ranged from 0.1 - 4.0 mg/l, with higher values having been recorded at times of low flow. The actual distribution of the test results from June, 1961 through June, 1966 has been as shown in Figure 8.

It must be remembered when evaluating the phosphate data that 1.0 mg/l of phosphate (PO_4) represents a phosphorous (P) concentration of 31/95 or about 0.326 mg/l. Thus, the critical level of 0.01 mg/l for inorganic phosphorous (P) is represented by a phosphate (PO_4) level of about 0.029 mg/l. It should also be noted that the ammonia nitrogen level of the river water does not represent the total inorganic nitrogen concentration because nitrogen in the nitrite and nitrate forms could also be present in significant amounts. That

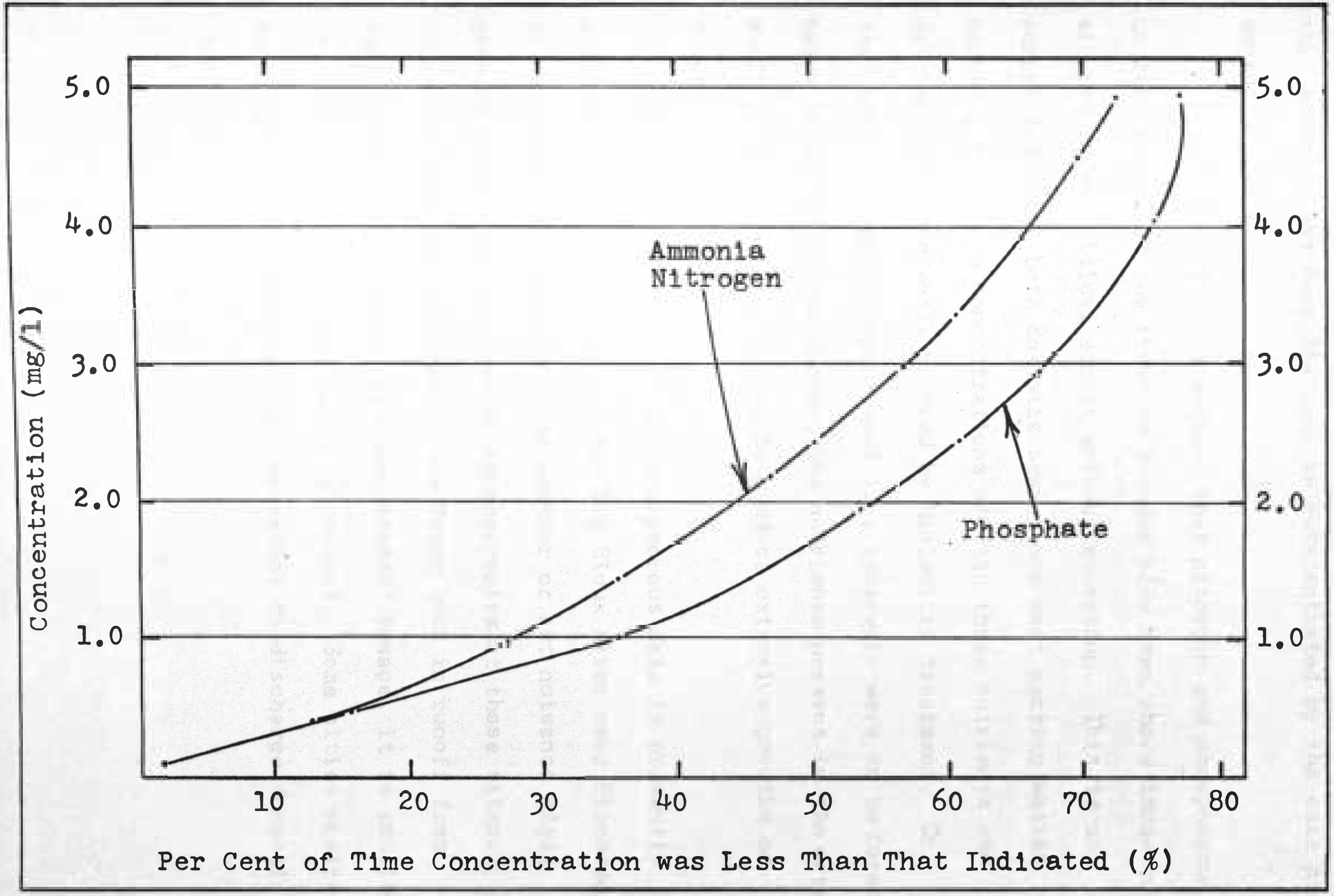

Figure 8. Distribution of Ammonia Nitrogen and Phosphate Analyses, Big Sioux River at Brandon, South Dakota, (June, 1961 - June, 1966).

this actually has been the case is substantiated by the data presented in Table 7.

From Figure 8 it is obvious that nitrogen and phosphorous concentrations of the river at Brandon have been above those considered to be critical almost without exception. This is not surprising since both domestic sewage and meat packing wastes normally have high concentrations of both these nutrients and neither are efficiently removed by biological treatment. On this basis, it would appear that if a reservoir were to be formed below Sioux Falls near Canton, the nutrients present in the water would be more than sufficient to produce extensive growths of algae.

Insufficient nitrogen and phosphorous data is presently available for Skunk Creek and the Big Sioux River near Flandreau to make logical judgments as to whether or not nuisance algal growths could also be expected in reservoirs at those sites. Since nitrogen and phosphorous are found both in runoff from agricultural lands and in treated domestic sewage, it is possible that sufficient nutrients would be present. Some cities upstream from Flandreau as Watertown and Brookings do discharge domestic sewage to the river.

SUMMARY AND CONCLUSIONS

This study was undertaken to evaluate in so far as possible from existing data, the probable effects of the recently adopted water quality standards for South Dakota on the development of the Big Sioux River downstream from Sioux Falls. Particular emphasis was given to the effects upon the river of the wastewater discharges from Sioux Falls and the relationship of the present wastewater treatment processes to the actual water quality in the river. Areas in which further investigation is required were also delineated.

The evaluation presented herein established that wastewater flows from Sioux Falls have, in the past, made up over 50% of the total flow in the Big Sioux River downstream from the city for extended periods of time. While the amount of pollutant material which enters the river from natural sources has not been fully evaluated, the wastewater treatment at Sioux Falls does play a major part in downstream water quality especially when natural flow is low. It was also demonstrated that since the wastewater treatment plant at Sioux Falls has been enlarged, the quality of the Big Sioux River at Brandon has been sufficient to satisfy the requirements of the standards, with the exception of coliform counts.

Based upon this investigation, the following conclusions seem to be justified:

1. At present wastewater flows, the intermittent stream use category will be applicable to the Big Sioux River downstream from Sioux Falls a significant portion of the time, especially during the months of December through March. The frequency of this occurrence will increase significantly in future years unless some source of additional dilution water can be provided.

2. Sufficient water quality data is not available for the Big Sioux River above Sioux Falls in order to completely evaluate the effects of the city's wastewater discharges.

3. The excellent wastewater treatment provided at Sioux Falls has been the major reason that the water quality in the Big Sioux River downstream from the city would have met the standards, with the exception of coliform limits.

4. Disinfection of the effluent from the Sioux Falls wastewater treatment plant may be required to reduce coliform counts in the Big Sioux River to required levels.

5. Additional treatment facilities may be required at the Sioux Falls wastewater treatment plant to insure that the suspended solids concentration in the Big Sioux River does not exceed 30 mg/l at times of intermittent stream use.

6. In the past, dissolved oxygen concentrations in the Big Sioux River at Brandon have been significantly lowered at times of extremely low river flows.

7. Substantial quantities of high quality dilution water will be required from the proposed Flandreau and Skunk Creek reservoirs

for water quality control in order to realize maximum development of the Big Sioux River for the beneficial uses.

8. If the Big Sioux River is impounded downstream from Sioux Falls near Canton, extensive algal growths will probably limit the use of the reservoir.

RECOMMENDATIONS

Although this investigation has provided basic insight into the water quality of the Big Sioux River downstream from Sioux Falls and to what degree that quality may be affected by wastewater discharges from the city, there is a definite need for further investigation. A few possible suggestions are outlined below:

1. An enlarged sampling program should be initiated downstream from Sioux Falls to monitor all parameters of water quality specified in the standards. At present, little or no data are available for suspended solids, nitrates, electrical conductivity, sodium adsorption ratio, and soluble sodium percentage.

2. Additional sampling should be initiated upstream from Sioux Falls to determine water quality in the Big Sioux River before it reaches the city.

3. The self purification capacity of the river downstream from Sioux Falls should be fully evaluated to determine the exact effects of the Sioux Falls wastewater on dissolved oxygen levels at several points downstream, and the pollutant loads the river is capable of assimilating without causing violations of the standards.

4. Sources of possible pollution other than the Sioux Falls wastewater, such as runoff from cultivated lands and feed lots should be identified and evaluated especially with regard to possible sources of coliform organisms.

5. Sampling of Skunk Creek and the Big Sioux River near Flandreau should be initiated to determine if nitrogen and phosphorous concentrations are sufficient to support extensive growths of algae on reservoirs which may be formed at those sites.

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APPENDIX A

Explanation of Frequency Codes as set forth in the Water Quality Standards for the Surface Waters of South Dakota (1-15)

Frequency Code	Sampling Base and Allowable Deviation
a	The value specified shall be maintained at all times without exception.
b	The value specified shall be maintained at all times based on the average of composite samples collected over a 24 hour sampling period. In addition, the concentration of the pollution characteristic shall not exceed 1.75 times the value specified for the material in any one grab sample collected during the sampling period.
c	The value specified shall be maintained at all times based on the average of composite or grab samples collected in a manner approved by the committee over a five day period. In addition, the concentration of the pollution characteristic shall not exceed 2 times the value specified for the material in any one grab sample collected during the sampling period.
d	The value specified shall be maintained at all times based on the average of composite or grab samples collected in a manner approved by the committee over a 30 day period. In addition, the concentration of the pollution characteristic shall not exceed three times the value specified for the material in any one grab sample collected during the sampling period.

APPENDIX B

Analysis of Periods when the Big Sioux River Downstream from Sioux Falls would have been in Intermittent Stream Use Category June, 1961 through March, 1967

POLLUTANT FLOWS

Pollutant flows to the Big Sioux River were computed as the monthly average daily flow from the Sioux Falls wastewater treatment plant plus 2.5 MGD of condenser water discharged directly to the river from John Morrell and Company. These two facilities are the only known significant contributors of wastewater flow to the Big Sioux River from the city of Sioux Falls.

The flow to the municipal treatment plant is composed of domestic sewage and industrial wastes primarily from John Morrell and Company. These two flows are metered separately as they enter the municipal plant. For certain months during the period for which this analysis was made, either or both of these two flow meters were out of service. For these months, estimated flows were required. These estimated flows are noted in Table B1 and the methods by which they were found are explained in the footnotes.

At no time during the period of June, 1961 through March, 1967 was the total wastewater flow as used in this analysis greater than 22.5 cfs. Therefore, the lowest value for river flow at Brandon at which the intermittent stream use could have applied was 45 cfs. Consequently, periods during which the river flow at Brandon was greater than 45 cfs were not analyzed in detail.

Table B-1. Intermittent Stream Analysis
(June, 1961 - March, 1967)

Calendar Year	Period	Total Pollutant Flow (MGD)	Twice Pollutant Flow (cfs)	Lowest River Flow (cfs)	Dates In Intermittent Stream (from - to)
1961	June 1-Jul 30	(Stream flow greater than 45 cfs)			None
	Aug	12.40(a)	38	39	None
	Sep	11.98(a)	37	28	11-26
	Oct	11.93(a)	37	27	5-31
	Nov	(Stream flow greater than 45 cfs)			1-4(b)
	Dec	11.91	37	24	10-31
1962	Jan	11.90(a)	37	16	1-31
	Feb	10.96(a)	34	14	1-28
	Mar	11.34(a)	35	14	1-27
	Mar 28-Dec 31	(Stream flow greater than 45 cfs)			None
1963	Jan	14.61	45	21	7-31
	Feb	14.61(c)	45	22	1-28
	Mar 1- Nov 30	(Stream flow greater than 45 cfs)			Mar 1-7(b)
	Dec	11.21	35	24	18-31
1964	Jan	10.59	33	18	1-31
	Feb	10.57	33	24	1-29
	Mar	11.11	34	32	1-11
	Mar 12-Jun 30	(Stream flow greater than 45 cfs)			None
	Jul	12.38	38	38	30-31
	Aug	11.98	37	23	1-31
	Sep	12.13	37	28	1-30
	Oct	11.29	35	19	1-31
	Nov	11.19(d)	35	20	1-30
	Dec	10.51(d)	33	10	1-31

Table B-1 (cont'd). Intermittent Stream Analysis

Calendar Year	Period	Total Pollutant Flow (MGD)	Twice Pollutant Flow (cfs)	Lowest River Flow (cfs)	Dates In Intermittent Stream (from - to)
1965	Jan	10.84	34	9	1-31
	Feb	10.60(e)	33	10	1-28
	Mar	10.79(e)	33	12	1-19
	Mar 19-Dec 31	(Stream flow greater than 45 cfs)			None
1966	Jan	11.45	35	15	14-31
	Feb	11.35	35	70	1-3(b)
	Feb 4-Jul 31	(Stream flow greater than 45 cfs)			None
	Aug	12.91	40	36	10-19
	Aug 20-Oct 30	(Stream flow greater than 45 cfs)			None
	Nov	12.18	38	31	9-19
	Dec	11.74	36	30	14-22;25-31
1967	Jan	11.8	37	10	1-31
	Feb	13.1	41	10	1-28
	Mar	12.3	38	282	1-7(b)
	Mar 8-Mar 31	(Stream flow greater than 45 cfs)			None

(a) No pollutant flow data is available for these months. Figures given are the average flows for these same months for which data is available from the years 1962 - 1966.

(b) Natural stream flow was greater than pollutant flow during this period but intermittent stream use was in effect since natural stream flow must exceed pollutant flow for seven consecutive days before the intermittent stream use no longer applies.

Table B-1 (cont'd). Intermittent Stream Analysis

(c) Flow to the wastewater treatment plant was taken to be the same as for January; no data is available for February. Years for which data is available show little flow variation between January and February.

(d) Flow to the wastewater treatment plant was computed as average domestic flow for the month plus the annual daily average industrial flow for the year. No industrial flow data is available for these months; industrial flow was quite constant throughout the year.

(e) Flow to the wastewater treatment plant was computed as the average daily industrial flow for the month plus the same domestic flow as for January. Years for which data for January, February, and March is available show little domestic flow variation among the three months.

RIVER FLOWS

The river flows utilized for this analysis were those compiled by the United States Geological Survey from the Big Sioux River gaging station at Brandon, South Dakota. These records from October 1, 1965 through March 30, 1967 were provisional and are subject to revision.